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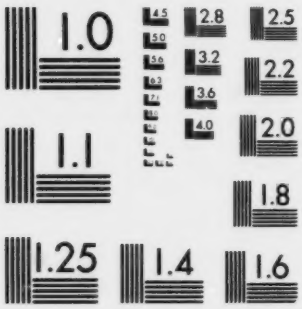

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ENFOR Project C-143

Identification of Hydrocarbon Emissions From Industrial Combustion of Forest Biomass and Biomass/Oil Mixtures

by

C.H. Wiesner

Energie de la Forêt / Energy from the Forest

Canada

Contractor's Final Report [1]
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Identification of Hydrocarbon Emissions From Industrial Combustion of Forest Biomass and Biomass/Oil Mixtures

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[1] This report has been reviewed by the Canadian Forestry Service and approved for distribution. Approval does not necessarily signify that the contents reflect the views and policies of the Canadian Forestry Service. Mention of trade names or commercial products does not constitute recommendation or endorsement for use.

March 1983

INTRODUCTION

. In recent years the sharply rising cost of fuel oil has led to a dramatic increase in the use of biomass as an alternative energy source. Initially, the greatest changes in use patterns have been in the area of primary and secondary residential space heating. A lack of familiarity with biomass handling and availability together with significantly higher capital cost of large scale industrial biomass burners as compared to conventional oil or coal fitted installations has resulted in slower industrial conversion to biomass fuels. While growth on the domestic heating scene is, at present, greater than on the industrial scene, all types of biomass combustion are known to be major sources of hydrocarbon emissions. Of particular concern from a human health and environmental point of view are those products of incomplete combustion known variously as polycyclic aromatic hydrocarbons (PAH), polycyclic organic materials (POM), or polycyclic aromatics (PCA). This document will use the term PAH throughout.

Increased use of biomass fuels makes it imperative that we develope an in-depth understanding of the environmental implications of this change. Chemical characterization of fugitive emissions is an essential prerequisite to the assessment of the environmental impact of increased biomass utilization.

OBJECTIVES/FULFILLMENT:

The objectives of the project were identified as:

(1) To identify the quantities and chemical structures of hydrocarbons emitted during the combustion of biomass and biomass/oil mixtures.

(2) To estimate the health hazard (if any) associated with these hydrocarbon emissions.

(3) To correlate these emissions with burner operating conditions.

Objective #1 has been met. A series of representative PAH has been quantitatited to the limits of the GC/MS technique while C_{10}-C_{24} saturated

hydrocarbons were quantitated by both FID capillary GC and by GC/MS.

The health hazard associated with various PAH (objective #2) is largely known as a function of their individual toxicities or carcinogenicities. Considerable uncertainty, however, exists with respect to the relationships between exposure (dose) to a given material and health consequences. It is perhaps more meaningful to relate industrial biomass combustion emissions to other sources of PAH in the atmosphere, particularly since this study concludes that the incremental addition to the overall emission burden is likely to be minor.

Objective #3 has proven difficult. While the most obvious correlation, i.e. increased emission with low excess air is demonstrable by chemical analysis, the influence of minor changes in operating conditions including fuel type and moisture appear to be largely outweighed by natural variations in each system.

Consequently, no specific 'guidelines' for operation can be defined other than that optimizing combustion conditions via excess air, turbulent conbustion and burner design will minimize hydrocarbon emissions.

LITERATURE REVIEW

Manual and computerized searches of Chemical Abstracts, covering the period from 1970 to 1982, were conducted based on various combinations of the following keywords: AROMATIC, BENZO-A-PYRENE, COMBUSTION, EMISSION, FUEL, HYDROCARBON, OIL, PEAT, POLYCYCLIC, POLYNUCLEAR, SMOKE, STACK, WOOD.

The total number of computer search hits was 485. These were then printed off-line. Perusal of the titles indicated that 37 were apparently relevent. These publications, together with several papers found manually, constitute the basis of the following review.

* * * * *

Tha vast majority of publications reviewed dealt primarily with emissions

from residential wood burners (2, 3, 4, 11, 13, 14, 17, 18, 19, 23, 26, 27). A brief overview of these publications is useful since the combustion processes and emission chemistry of domestic appliances are not categorically different from their industrial counterparts. The residential wood stove may be viewed as a "worst case" emission situation due primarily to the following three points:

(1) Fueling is conducted on a batch basis resulting in extreme cycling of combustion conditions from "smoulder" to a vigorous turbulent burn.

(2) Absence of any emission control.

(3) Operation under "starved" conditions is very common in the currently favored "air-tight" stoves.

It is estimated (4, 13, 18) that since the mid seventies between one and two million wood burning appliances per year are being installed in the United States alone. Winter air quality studies have suggested (3, 18) that as much as one third of respirable particulates in some urban areas result from wood burning.

While wood use is still limited compared to other fuels, residential heaters appear to provide a disproportionate share of the emission burden. In fact, one EPA study (19) concludes that as much as 80% of the US national emission burden of PAH may be due to residential wood combustion. However, this estimate excludes natural and mobile emission sources. Attempts to assess the impact of residential combustion on air quality have been severly hindered by a lack of standard techniques such as are commonly used for emission characterization of large industrial installations. The situation is further complicated by the vast diversity of domestic appliances and the range of homeowners operating experience (17, 23).

A number of studies (3, 4, 11, 13, 18, 27) have documented significant amounts of PAH in domestic emissions. Due to the established carcinogenic properties (32) of some of these compounds most analytical studies have concentrated upon this chemical family.

Concerns that fuel type might significantly affect hydrocarbon emissions have largely been discounted except in the case of green pine (4, 13) which has

been shown to dramatically increase organic emissions.

Instead it appears that the dominant effect is the completeness of the combustion which in turn is influenced by operating variables such as stove design (13, 18, 26, 27) fuel loading (3) and excess air. The latter effect (excess air) has been demonstrated repeatedly (13, 14, 19) in terms of hydrocarbon emission factors which may vary from 1g/kg (fuel) to 25g/kg. Additionally, one study (19) was able to establish an inverse correlation between biological activity of emission samples (Ames test and cytotoxicity) and excess air.

A number of studies (12, 17, 22, 23) lead to the same, possibly unexpected, conclusion, i.e. that emissions from residential wood burning pose a much greater problem to air quality than do those from industrial biomass burners. In retrospect this statement is not unreasonable in view of the greater level of sophistication in industrial burner design. Most industrial burners are specifically built to optimize those parameters which most influence incomplete combustion and hence hydrocarbon emission. Finally, those organic particulates which do escape complete combustion are largely (6, 16, 25) removed by various emission control devices.

The physical nature of hydrocarbons generated during combustion is significant since it influences both experimental sampling results as well as the performance of various emission control devices.

While there is evidence for direct association between PAH and particulate (3, 10), this appears to be related closely to sampling temperature (10, 20, 21, 28). At temperatures above 150°C significant proportions of PAH are in the vapour phase whereas at temperatures commonly found post emission (< 40°) essentially quantitative adsorption is found. Furthermore, the conversion process from vapour to particle-adsorbed PAH is very rapid following temperature drop (21).

As was mentioned above there is little evidence for any significant relationship between fuel type and hydrocarbon emission. What effects have been found (4, 13) relate to increased particulate when burning green pine and are probably more a function of burning conditions than chemistry. However, one

fuel-related effect has been reported which may be chemically mediated. A Swedish study (28) of PAH emission during the combustion of hardwood chips versus peat in a 2MW boiler concluded that total PAH emitted during peat combustion was 9.7 times greater per cubic meter of flue gas than from wood chip combustion. Also, comparison of PAH structures showed a pronounced tendency toward emission of higher molecular weight compounds by peat than by wood.

While the author suggests that combustion conditions may account for the order-of-magnitude difference in PAH emission, there is evidence (30) that waxy, lipoidal substances are 10-200 times more effective pyrosynthetic precursors of PAH than are highly oxygenated organics such as sugars and cellulose. Since the presence of waxes in peat is established, this mechanism may contribute to the observed trend.

* * * * *

Modelling studies as well as emission assessment studies of industrial wood burning installations (9, 16, 22, 25) have led to very positive conclusions with respect to impact on air quality. In 1978, wood fired boilers in the United States (excluding pulp and paper recovery furnaces) had a total heat input of approximately 0.5×10^{15} BTU per annum (33). Economic and other restraints are estimated to limit the expansion of this capability to 1.5×10^{15} BTU. Based upon this assumption and using an EPA computer modelling technique for determining the incremental impact of stationary sources on the environment it was concluded (22) that as long as existing regulations are enforced, the impact of using an additional 10^{15} BTU from wood and bark residue fuels will be minimal and will not result in human health hazards. This paper gives an interesting comparison of gaseous pollutants resulting from combustion of thermally equivalent quantities of wood and coal. While on one hand wood generates more carbon monoxide (2.98:1) and hydrocarbons (9.93:1) than coal, it produces lesser amounts of nitrogen oxides (0.45:1) and sulphur dioxide (0.14:1). It is also noted that at particulate levels required to meet primary National Ambient Air Quality Standards (NAAQS), particulate emissions form wood and bark fuels were judged to be not toxic, not carcinogenic and not mutagenic. An EPA environmental assessment of an 8MW wood/oil co-fired boiler (16) concluded that while the

three ash streams (bottom, primary collection and secondary collection) contained some hazard, stack emissions showed a relatively low degree of hazard.

A recent report (25) describes in detail the process undertaken at a Proctor-Gamble manufacturing facility on Staten Island involving regulatory negotiations and plant design in the conversion of an existing gas and oil fired boiler to wood. Following extensive documentaton of reduced total emissions and spin-off economic benefits permit approvals were issued.

Several publications (6, 8, 12, 15, 24, 29) deal with emissions from industrial combustion processes which utilize a variety of fuels, particularly municipal refuse alone and in combination with coal.

The main difference between these processes and those involving only biomass and biomass/oil combinations is the presence in the emissions of a large variety of compounds of synthetic or retrosynthetic origin, e.g. plasticizers, industrial monomers, pesticides, PCBs and siloxanes. Since these arise from combustion of man-made materials, they do not fall within the scope of the present study except to point out that if and when such materials, either by design or by accident, are mixed with biomass fuels the chemical composition of the resulting emissions will be radically and unpredictably affected.

METHODS

Sampling

Stack gas samples were taken at three different facilities in New Brunswick under sub-contract to Dr. F. R. Steward, Department of Chemical Engineering, University of New Brunswick.

(1) Maritime Forest Ranger School, Fredericton.
Woodchip fired boiler. Samples M3 - M13.

(2) Pulp and paper mill.
Hog fuel/oil fired boiler. Samples M14-M19.

(3) Lameque Peat Boiler.
Peat/oil fired boiler. Samples 01-05.

At each facility stack samples were taken under a variety of burner operating conditions. The variables assessed were fuel type and fuel moisture, firing rate and excess air. The combustion parameters and stack conditions are shown in Tables 1-3.

At the Maritime Forest Ranger School the sampling section was from a rectangular duct (4 ft.^{2}) leading to the outside stack, while the sampling port at the paper mill was directly on the side of the nine-foot diameter circular stack. A Model 2343 Staksampler (Research Appliance Company, Gibsonia, PA.) was the principal apparatus. Also used were an Orsat gas analyzer, two Fyrite gas analyzers, and a smoke-test pump (Bacharach Instruments, Pittsburg, PA.).

In each case, a probe with a pitot tube attached was used to collect the gas samples and particulate matter while measuring the velocity of the flow. At the Forest Ranger School, a seven-foot probe was inserted vertically into the stack, while an eleven-foot probe was inserted horozontically at the mill. At Lameque the procedure was essentially the same as that at the Ranger School except that the probe was inserted horizontically as the stack was vertical at the point of testing. The gas sample would pass through a particulate-collecting flask and cyclone, onto a flass fibre filter which would trap the remainder of the larger particles, and thereafter to a series of four glass impingers

containing water. The final unit in the chain was a column filled with an adsorbing resin that collected any remaining organic matter. The probe had a nozzle at its tip, always pointed in the direction of the gas flow. The size used depended on the measured stack conditions.

The tests were conducted at each site under varying fuel and firing conditions. At the Forest Ranger School the variables considered were type of fuel (hardwood or softwood) and CO_2 percentage. At the paper mill the proportion of hog fuel to oil was the variable considered. A preliminary set of runs was conducted at the Forest Ranger School to gain operating experience and the nature of the results expected.

Five exploratory runs were made followed by eight runs under reasonably well controlled conditions. Six runs were performed at the mill.

For correct results from the sampling, there are several requirements. Equal areas must be sampled at each traverse point of the stack; that is, each point must represent 1/n of the total area of the stack, where 'n' is the number of sample points. Each point should be sampled for an equal time period. Most importantly, the collection of gas should be as near as possible to the actual stack gas velocity, that is, isokinetic. A manometer attached to the main sample train is capable of being adjusted to ensure this condition after computations performed by the operator.

Following is a more detailed description of the individual runs M3-M13 for the Forest Ranger School, M14-M19 for the paper mill. The results will be discussed and an attempt made to explain problems that were encountered.

Before each run and after each movement of the probe, the following measurements were taken: stack temperature, velocity head (change in pressure), orifice pressure differential (ΔH), gas sample volume, gas temperature at dry gas meter (inlet and outlet), sample box temperature, and temperature of gas leaving last impinger. The sample box, containing all the glassware, is maintained at about the same temperature as the stack by a heater to ensure similar sampling conditions. Carbon dioxide and oxygen measurements were taken before and after the run, a smoke test was conducted and a grab sample

of stack gas collected. The nozzle size for the probe was determined from the preliminary set of observations, and isokinetic sampling maintained as a function of these results.

At the Forest Ranger School the seven-foot probe was used and inserted vertically into the stack at distances of six, twelve and eighteen inches for about twenty minutes at each point.

At the paper mill the same manner of testing was carried out except that an eleven-foot probe was pushed horizontically into the nine-foot diameter stack. The sampling points were determined by separating the stack into equal areas. Six points were tested: at 5, 16, 32, 76, 92 and 103 inches across the stack diameter. the exception to this was Run M15, where the seven-foot probe had to be used because of damage to the larger appartus. The points used in this test were 2.3, 7.2, 12.7, 19.1, 27.0 and 38.3 inches.

Chemical Analysis

The sampling train was designed to provide some degree of prefractionation of the stack emissions. It was anticipated that the well-established (3, 10) preferential sorption of higher molecular weight PAH on soot and ash particles would cause most of these materials to be retained in the cyclone and on the glass fibre filter. The water-filled and ice-cooled impingers were expected to trap the majority of volatile organics while cooling the gas stream to prevent thermal degradation of the subsequent polymeric resin trap (3g Porapak Q^R 60-80 mesh). The resin which has high capacity and low breakthrough for virtually all volatile organic species was precleaned by a method developed at RPC which virtually eliminates resin-derived background interferences in subsequent gas chromatographic ayalyses of methylene chloride extracts of the resin. The method involves heating the Porapak in a nitrogen stream at 200-220°C for twenty hours followed by another twenty hours at 100°C followed finally by soxhlet extraction with hexane.

As a result of this sampling train, each sample was broken down into four subsamples: (1) particulates (filter paper, cyclone, etc.) (2) Disc core (3) impinger water (4) resin. (The disc core sample consisted of acetone washes of

the sintered glass plate which supports the glass-fibre filter. The core showed significant amounts of condensed tarry material.).

All samples were extracted with methylene chloride, dried and reduced to 1-2 ml under nitrogen (filter-soxhlet, 3-4 hrs; impinger- water-3X 100 ml, resin-15 ml eluate).

Each methylene chloride subsample extract was then fractionated by silica gel chromatography. Columns were eluted sequentially with hexane, methylene chloride, 50% methylene chloride/diethyl ether and 20% methanol/ether. Recovery and breakthrough experiments were conducted at each stage with saturated hydrocarbon and PAH standards. The silica gel fractionation was shown to elute alkanes in fraction I (hexane) and PAH in fraction II (methylene chloride) with no PAH breakthrough in fraction I. More polar organics eluted in fractions III and IV.

Preliminary gas chromatographic analysis of selected subsamples and chromatographic fractions revealed a number of unexpected problems.

(1) Very little difference was found in the basic chemical profiles of the various subsamples (filter, core, impinger, resin). Apparently, significant proportions of even relatively high-boiling organic compounds were in the vapour phase and were being partially trapped at all stages. This effect has now been well documented in the literature (20, 21).

(2) Many samples were found to contain massive amounts of compounds clearly unrelated to biomass combustion, primarily phthalate plasticizers and organosilyl compounds. These contaminants were present at such high levels that they tended to overwhelm the chromatographic clean-up procedure, breaking through into the PAH fraction and completely obscuring the more polar fraction III.

These problems necessitated a complete reevaluation of the analytical approach. Following consultation with the scientific authority for the contract, Mr. D. Huffmann of Forintek, the following approach was adopted.

Fraction I-III of all subsamples (filter, core, impinger and resin) were recombined so as to essentially revert to one composite sample per run. Each sample was then refractionated on 5.5g of activated silica gel in a one cm (i.d.) column by elution with 25 ml hexane (Fraction I), 15 ml methylene chloride (Fraction II) and 15 ml diethyl ether (Fraction III) Fraction III was dominated by the relatively polar contaminants and was not further considered. Fraction I of most of the runs contained primarily n-alkanes from C_{10} to C_{24} as major peaks. These hydrocarbons were quantitated by capillary gas chromatography using a flame ionization detector. (Varian 3700-FID; 20m SCOT column at 8 psi hydrogen, splitless injection at 30°C, 30 second hold, raised to 65°C, 60 second hold, then programmed at 8°C/min to 220°C).

In runs M4, M11 and M12 n-alkanes were obscurred and required quantitation by gas chromatography/mass spectrometry (GC/MS). These samples were run as follows: (Finnigan 4021 GC/MS; 30m DB-5 column at 10 psi helium, splitless injection at 30°C, held 60 seconds, then programmed at 30°C/min to 150°C followed by 10°C/min to 220°C. Electronmultiplier 1300 volts, Electron energy 60 volts).

Fraction II containing aromatics and PAH was analysed by capillary GC/MS (Finnigan 4021; 30m DB-5 column at 10 psi helium; splitless injection at 30°C held for 60 seconds, then 30°C/min to 150°C, then 10°C/min to 260°C. Electronmultiplier 1300 volts, Electron energy 60 volts, data acquisition was started 3.5 minutes after injection scanning at 1.5 sec/scan from 45 to 350 atomic mass units). The run was continued for approximately thirty minutes at which time the perylene standard was eluted.

It was discovered that small amounts of methylated naphthalanes and other low molecular weight PAH had broken through into Fraction I. Consequently, Fraction I of all samples were reanalysed by GC/MS for PAH and the results combined with those from Fraction II to provide a summed value for each PAH in each sample. Each PAH component was quantitated by integrating the area generated from the base peak of each mass spectrum.

When available, authentic standards were used to quantitate each PAH.

Those compounds for which standards were not available were quantitated by means of a mass spectrally closely related compounds.

Twenty-four individual PAH were searched and quantitated in each sample. The actual number of compounds assessed is somewhat higher since the method does not distinguish between positional and skeletal isomers of some of the compounds, e.g. phenanthrene and anthracene.

Once the quantitation of specific PAH compounds was complete, attention was turned to the major peaks in the GC/MS reconstructed chromatograms; all major and many minor peaks were scrutinized.

This is done as follows. The mass spectrum recorded at the apex of each peak is background subtracted and the resulting "clean" spectrum is computer matched against all spectra in the computer library. The library contains over 25,000 edited spectra. The computer then displays the five best matches and ranks each of these library spectra against the sample spectrum for fit on a scale of 0-1000. A ranking in the vicinity of 900 indicates almost certain identity. Obviously, if the sample spectrum is not represented in the library, it cannot be matched. However, the spectra and ranks which the computer generates generally provide a good indication of the class of compound to which the sample peak belongs.

Interpretation of the mass spectrum (both manually or by computer) can be complicated if the peak is unresolved, i.e. if more than one compound elutes at the same time. the observed mass spectrum will then be a composite one, which may be difficult to deconvolute.

The problem is minimised by using capillary GC columns which provide the best resolution presently available. However, with mixtures as complex as combustion emissions poor resolution is frequently encountered.

RESULTS

The analytical results for n-alkanes at the three installations are presented in Tables 4, 5, 6 while the PAH quantitation results are shown in Tables 7, 8, 9.

Figures 1-21 show the GC/MS reconstructed total ion chromatograms (RIC) for Fraction II of all samples. Tables 10 to 30 provide a list of the best computer matches for all major peaks by scan number accompanied by the numerical fit as described above.

DISCUSSION

It is immediately apparent from both the GC/MS RIC traces and the computer match tables that many of the samples were grossly contaminated by three classes of compounds. Most of the contaminants had been removed by the fractionation procedure but the levels were so high that significant amounts broke through into the PAH fraction (II).

The contaminants are of three structural types. The most readily identifiable being phthalate esters. These compounds were most efficiently removed by the fractionation procedure and appear as significant peaks in samples M3, M12 and M13 and 05 only.

The most ubiquitous contaminants and those which were least effectively removed are a series of organosilyl compounds. All of these compounds were recognizable from their mass spectra as containing silicon but only one is considered to be fully characterized. A compound eluting at scan number 51 or 52 repeatedly had fit values in excess of 900 for octamethyl cyclotetrasiloxane. The other compounds of this class had such low fit values that while the general nature of the compounds is assured, it is unlikely that any of them were, in fact, identical to the computer library reference materials.

The third class of compounds were distributed over a wide range of elution times from scan number 156 to 534 and were characterized by

fragments at m/e 57, 71 and 113. These fragments are characteristic of branched saturated hydrocarbons but the computer matched them repeatedly with 2-bromo octane. At present we have no further indications as to either structure or source.

The origin of these contaminants is unclear. They cannot have arisen through laboratory contamination since none of the hundreds of other GC/MS samples processed in the laboratory showed any contamination. Silicone lubricant used in the sampling train was checked and found to be clean. The nature of the compounds is similar to materials detected from refuse incineration emissions (12, 29). This is not surprising in view of the wide spread industrial use of phthalate plasticizers and silicon rubbers. However, how these materials found their way into stack gases from combustion of biomass and biomass/oil is unsolved.

Review of the analytical results immediately suggests a number of qualitative conclusions:

(1) Higher molecular weight PAH are found more frequently in the chip burner emissions than in either the hogged fuel burner or the peat burner.

(2) Overall PAH levels are lowest in the hogged fuel burner.

(3) In all situations, low excess air is associated with enhanced PAH levels.

On the other hand, some expected correlations such as between fuel type and hydrocarbon emission and between particulates and hydrocarbons are not readily apparent. Even the general associations such as excess air and lowered hydrocarbon levels, while demonstrable between similar runs on the same boiler (e.g. M6, M7 and 04, 05) are not quantifiable within one run series let alone between boilers. These problems have been observed in numerous other studies (4, 27, 28) and lead inevitably to the conclusion that the most influential factor in determining the quantity and quality of emitted hydrocarbon is the design and operation of the combustion chamber.

Combustion zone temperature, turbulence and residence time are likely to be dominant parameters affecting the production of hydrocarbons, particularly PAH.

It has been estimated (22) that while the combustion of wood produces ten times as much gaseous hydrocarbons as does coal, the benefits in reduced NO_x (approx. one half) and sulphur dioxide (approx. one tenth) emissions provide a distinct environmental advantage. In view of the extreme variability in total hydrocarbon emission with apparently unaccounted combustion parameters it is questionable whether such comparisons are meaningful for hydrocarbon emission. The values for nitrogen and sulphur oxides, however, being related to elemental composition of the fuel should be entirely valid.

When expressed in relation to the combustion of a unit of dry fuel the total PAH emissions encountered in this study, in general, vary between about 1,000 and 10,000 ug/kg. These values compare favourably with the 1,100-2,400 ug/kg described in the Swedish study of a 2MW wood-chip boiler (28); particularly in view of the fact that none of the three installations in the present study used any emission control devices while in the Swedish boiler a multiple-cyclone collector was used. Total PAH emissions from residential stoves vary much more widely between stove models and different studies. An EPA study (4) found total PAH ranging from about 190,000 ug/kg to 370,000 ug/kg. On the other hand a Norwegian study (27) found values between 2,600 ug/kg and 32,300 ug/kg from a small residential baffled wood stove.

In summary, the combustion of biomass produces hydrocarbon emissions which are qualitatively very similar to those produced by combustion of fossil fuels. The quantitative impact of industrial biomass combustion on air quality is unlikely to be important in comparison to emissions from residential heating systems which are the single largest source of PAH accounting for between 40 and 80% of all PAH emissions from stationary sources in the United States.

Provisions for efficient combustion (22) together with standard emission control practices (6, 16, 25) should be effective in preventing appreciable environmental impact from industrial combustion of biomass.

TABLE 1a

Preliminary Tests on Maritime Ranger School Boiler

Sample No.	Fuel Conditions		Firing Conditions			Stack Conditions	
	Fuel Type	% Moisture in Fuel	Fuel Firing Rate ft^3/min	Stack Concentrations O_2	% CO_2	Stack Temperature °F	Particulate Concentrations gr/scf
M2*	Softwood	114.6	-	18.7	0.1	430	.125
M3	Softwood	99.0	-	18.0	0.1	400	.115
M4	Softwood	125.8	-	18.7	0.3	303	.085
M5*	Hardwood	31.8	-	20.2	0.8	321	.039

* Not analysed.

TABLE 1b

Tests on Maritime Ranger School Boiler

Sample No.	Fuel Conditions: Fuel Type	Fuel Conditions: % Moisture in Fuel	Firing Conditions: Fuel Firing Rate ft^3/min	Firing Conditions: Stack Concentrations O_2 %	Firing Conditions: Stack Concentrations CO_2 %	Stack Conditions: Stack Temperature °F	Stack Conditions: Particulate Concentrations gr/scf
M6	Hardwood	29.9	0.86	14.9	6.4	530	.081
M7	Hardwood	35.1	0.30	19.0	2.2	324	.044
M8	Hardwood	55.5	0.47	17.2	5.8	408	.020
M9	Hardwood	67.5	0.49	17.5	3.0	372	.015
M10	Softwood	24.3	0.45	17.0	5.6	375	.017
M11	Softwood	23.5	0.34	19.1	2.0	370	.061
M12	Softwood	54.3	0.38	18.2	2.9	360	.030
M13	Softwood	55.0	0.71	16.8	5.8	428	.022

TABLE 1C

Tests on Maritime Ranger School Boiler

Sample No	Volume of Sample Collected scf dry gas	Volumetric Flow Rate of Stack Gas scf dry gas/min	Volume of Stack Gas per unit of Fuel Fired $\frac{\text{scf dry gas}}{\text{lb dry wood}}$
M6	9.26	1810	260
M7	17.01	1480	609
M8	22.40	1200	314
M9	10.94	3210	809
M10	26.64	1300	494
M11	12.41	1500*	752*
M12	17.46	1530	686
M13	20.46	1320	321

*Stack gas flow rate based on final 20 minutes of run as sampling difficulties were encountered during first two positions of probe.

TABLE 2a

Tests on Pulp Mill Boiler

Sample No.	Fuel Conditions		Firing Conditions		Stack Conditions	
	Fuel Composition % Hog Fuel (Based on Btu)	% Moisture in Hog Fuel	Stack Concentrations O_2 %	CO_2	Stack Temperature °F	Particulate Concentrations gr/scf
M14	100	130	14.5	6.3	340	.030
M15	0	-	13.3	6.4	310	.044
M16	80	162	14.2	9.0	300	.054
M17	85	139	9.1	13.0	390	.023
M18	59	92	12.2	7.2	330	.024
M19	94	61	14.0	6.0	390	.052

TABLE 2b

Tests on Pulp Mill Boiler

Sample No.	Fuel Firing Rate: Hog Fuel as Fired lbs/hr	Fuel Firing Rate: Oil lbs/hr	Volume of Sample Collected scf dry gas	Volumetric Flow Rate of Stack Gas scf dry gas/hr	Volume of Stack Gas per unit of fuel fired $\frac{\text{scf dry gas}}{\text{lb dry fuel}}$*
M14	29,700	-	100.04	12.44×10^6	964
M15	0	5200	68.03	2.12×10^6	408
M16	16,900	750	50.07	2.34×10^6	325
M17	52,300	1800	54.41	2.55×10^6	107
M18	10,700	1800	57.82	2.71×10^6	366
M19	8,100	150	57.12	2.67×10^6	477

*Includes Hog Fuel and Oil

TABLE 3a

Tests on Lameque Boiler

Sample No.	Fuel Conditions: Fuel Type	Firing Conditions: Firing Rate Peat as fired lbs/hr*	Firing Conditions: Firing Rate Oil	Stack Conditions: Stack O_2 %	Stack Conditions: Stack CO_2 %	Stack Conditions: Stack Temp °F	Stack Conditions: Particulate Concentration gr/scf
01	Peat + Oil	1005	215	17.4	3.6	283	.066
02	Peat + Oil	2010	215	14.5	7.6	320	.049
03	Peat + Oil	3700	198	13.7	7.9	300	.060
04	Peat + Oil	2902	215	4.2	16.0	272	.067
05	Peat + Oil	2902	74	13.6	6.2	323	.152

*Peat as fired contained 60% moisture before entering drier. Approximately 54% of moisture removed by drier before entering boiler combustion chamber

TABLE 3b

Tests on Lameque Boiler

Sample No.	Volume of Sample Collected scf dry gas	Volumetric Flow Rate of Stack Gas scf dry gas/min	Volume of Stack Gas per Unit of Fuel Fired scf dry gas/lb dry fuel**
01	34.98	10,700	1045
02	59.47	9,100	537
03	56.82	8,700	312
04	38.58	11,800	516
05	13.06	4,000	195

**Includes Peat and Oil

	Carbon Number														
Sample	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
M3*	0.27	0.17	0.09	0.07	0.20	0.19	0.31	0.40	0.41	0.35	-	0.17	0.16	-	-
M4*	-	-	-	-	8.85	18.5	9.38	3.70	2.32	1.64	0.76	-	-	-	-
M6	1243.2	394.8	216.16	127.12	123.48	99.96	78.12	68.04	79.24	23.8	15.12	12.88	15.12	20.44	31.36
M7	111.7	952.3	1747.0	2004.8	1718.4	1446.3	1152.8	866.36	537.	390.2	181.86	97.4	74.5	60.1	57.28
M8	13.4	19.18	25.6	411.6	97.0	73.9	68.9	67.6	51.4	44.0	42.8	17.5	14.1	15.5	17.5
M9	1618.4	5490.8	7611.7	4921.7	2387.	864.6	521.7	407.9	329.6	237.2	187.7	91.6	116.8	273.4	182.5
M10	116.6	143.2	366.3	270.1	138.8	99.9	59.6	50.7	39.6	32.6	28.1	22.6	21.8	27.	36.3
M11	-	-	-	-	-	155.1	130.3	115.7	56.4	56.6	24.2	-	-	-	-
M12	-	-	-	165.5	452.	134.5	99.0	59.3	51.9	35.8	15.7	-	-	-	-
M13	299.9	17.7	-	-	43.8	67.2	49.3	33.1	28.7	20.1	9.7	7.2	9.0	9.7	10.5

* uncorrected.

TABLE 4

EMISSION OF N-ALKANES AT MARITIME FOREST RANGER SCHOOL
EXPRESSED AS MICROGRAMS PER POUND OF DRY FUEL

	Carbon Number														
Sample	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
M14	209.3	112.3	45.1	42.3	70.	114.2	100.8	98.4	53.8	49.0	18.2	12.7	11.6	14.9	24.5
M15	-	-	2.5	7.6	17.3	46.6	56.3	57.2	46.7	37.9	19.1	9.7	7.08	6.4	8.3
M16	7.7	4.8	5.2	11.1	26.6	59.3	87.1	103.4	88.4	65.7	27.3	10.1	5.4	8.7	9.3
M17	29.4	14.5	12.9	12.52	11.7	14.86	13.	15.3	13.4	10.6	4.7	2.2	1.74	1.6	1.78
M18	6.3	3.8	3.	5.2	12.7	38.3	49.5	64.9	61.4	39.9	17.6	9.0	7.3	7.3	7.9
M19	45.7	23.5	6.2	4.7	8.3	73.7	29.	37.7	34.5	31.2	12.9	6.4	4.5	4.1	4.7

TABLE 5

EMISSION OF N-ALKANES AT PULP MILL
EXPRESSED AS MICROGRAMS PER POUND OF DRY FUEL

Sample	Carbon Number														
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
O1	113.5	158.2	37.3	32.8	43.2	96.3	115.3	143.9	117.1	124.9	73.0	37.3	25.0	18.2	16.7
O2	141.3	87.21	66.8	43.7	60.4	97.2	90.	148.5	116.1	88.7	42.4	17.5	11.9	11.1	5.9
O3	149.1	31.2	20.8	11.2	10.8	37.3	30.8	48.2	50.2	41.4	20.5	10.2	7.3	6.8	8.5
O4	422.1	406.	361.8	285.4	412.7	306.9	269.3	178.2	119.7	103.7	102.4	43.4	51.5	20.5	24.7
O5	-	-	.45	.45	1.65	3.75	8.4	13.95	7.5	10.95	5.7	5.55	7.5	9.6	11.85

TABLE 6

EMISSION OF N-ALKANES AT LAMEQUE PEAT BURNER
EXPRESSED AS MICROGRAMS PER POUND OF DRY FUEL

Compound \ Sample Number	M3*	M4*	M6	M7	M8	M9	M10	M11	M12	M13
naphthylene	0.22	265.	599.2	101.	175.	2645.6	95.5	329.1	888.2	102.4
methylnaphthylene	.20	331.	186.8	179.	152.6	1581.5	43.3	579.3	1116.1	52.9
dimethylnaphthylene	-	108	26.3	-	114.8	-	-	696.9	727.1	-
1-(2-propenyl) naphthylene	-	10.5	-	5.7	8.4	90.2	34.4	56.4	31.4	16.5
2-(phenylmethyl) naphthylene	-	0.35	16.8	37.2	20.7	59.9	28.5	51.5	37.7	13.8
biphenyl	0.06	8.97	-	67.3	24.1	172.2	31.1	73.9	103.4	-
methylbiphenyl	-	-	118.2	28.6	14.8	68.7	20.4	-	41.7	6.3
acenaphthylene	0.22	127.	5.9	41.5	33.6	124.2	-	606.	471.6	15.4
acenaphthene	0.02	61.8	.6	-	4.3	23.6	-	73.3	73.9	1.3
dibenzofuran	0.19	21.0	165.2	127.5	83.0	322.2	40.3	854.5	1124.	90.6
fluorene	0.19	33.8	30.2	27.2	27.7	107.9	3.7	173.3	367.9	9.7
phenanthrene/anthracene	1.87	38.5	74.8	43.	68.5	74.6	7.03	432.7	209.9	21.4
methylphenanthrene/ 4,5 methylenephenanthrene	1.13	19.1	-	81.6	30.5	73.2	8.9	158.2	126.6	5.8
tetramethylphenanthrene	0.52	1.79	5.0	28.6	31.2	25.1	3.7	12.1	40.1	1.2
fluoranthene	2.31	10.8	5.9	12.9	15.5	28.1	2.6	79.4	39.7	10.7
pyrene	3.24	10.3	3.4	10.0	10.8	19.2	1.9	33.9	28.3	2.7
methylpyrene	0.86	2.54	22.7	-	-	-	-	1.2	-	-
benzo (a) anthracene	2.02	4.68	-	1.4	3.6	2.2	-	-	4.7	.31
chrysene	1.93	4.59	.56	2.9	5.2	3.7	-	-	7.1	1.3
benzo (e) pyrene	1.55	2.20	-	-	2.0	-	-	-	-	-
benzo (a) pyrene	1.98	2.93	-	-	-	-	-	-	-	-
perylene	0.32	0.35	-	-	-	-	-	-	-	-
	* uncorrected.									
TOTAL	18.8	1065.	1260.	794.	826.	5416.	320.	4211.	5423.	351.

TABLE 7

EMISSION OF PAH AT MARITIME FOREST RANGER SCHOOL
EXPRESSED AS MICROGRAMS PER POUND OF DRY FUEL

Compound \ Sample Number	M14	M15	M16	M17	M18	M19
naphthylene	48.2	38.8	4.0	5.4	20.7	17.8
methylnaphthylene	15.4	1.1	3.1	1.7	3.9	4.2
dimethylnaphthylene	-	-	1.1	-	.38	-
1-(2-propenyl) naphthylene	49.2	-	5.7	.86	37.0	2.7
2-(phenylmethyl) naphthylene	10.8	-	5.5	-	6.1	1.6
biphenyl	31.9	-	1.4	-	5.4	.66
methylbiphenyl	17.9	-	4.1	-	18.1	1.6
acenaphthylene	-	-	-	-	-	-
acenaphthene	-	-	-	-	-	-
dibenzofuran	3.5	-	3.5	-	5.7	-
fluorene	2.7	.6	.33	-	.44	1.4
phenanthrene/anthracene	19.4	2.8	1.8	.12	2.1	2.1
methylphenanthrene/ 4,5 methylenephenanthrene	3.7	3.5	4.1	-	5.0	1.9
tetramethylphenanthrene	1.9	4.8	4.9	-	4.0	2.4
fluoranthene	2.1	.84	2.9	.88	2.3	-
pyrene	11.1	13.8	18.	2.26	11.0	9.9
methylpyrene	-	-	-	-	-	-
benzo (a) anthracene	-	-	-	-	-	-
chrysene	.77	-	-	-	-	-
benzo (e) pyrene	-	-	-	-	-	-
benzo (a) pyrene	-	-	-	-	-	-
perylene	-	-	-	-	-	-
TOTAL	217.9	66.	60.5	11.2	121.6	45.7

TABLE 8

EMISSION OF PAH AT PULP MILL
EXPRESSED AS MICROGRAMS PER POUND OF DRY FUEL

Compound / Sample Number	01	02	03	04	05
naphthylene	536.4	118.8	38.	754.4	30.9
methylnaphthylene	55.1	26.5	6.4	613.7	4.7
dimethylnaphthylene	2.4	15.9	.39	106.1	-
1-(2-propenyl) naphthylene	381.4	99.9	-	-	-
2-(phenylmethyl) naphthylene	22.7	10.4	2.6	-	-
biphenyl	57.2	16.2	-	-	-
methylbiphenyl	280.1	67.1	5.7	18.9	-
acenaphthylene	-	-	-	8.0	-
acenaphthene	-	-	-	3.8	-
dibenzofuran	-	-	1.7	223.8	-
fluorene	-	-	-	29.8	-
phenanthrene/anthracene	23.2	8.6	2.9	78.8	3.2
methylphenanthrene/ 4,5 methylenephenanthrene	15.5	9.72	3.6	32.4	-
tetramethylphenanthrene	5.7	.36	.22	.4	-
fluoranthene	4.8	.54	.28	2.4	.6
pyrene	18.2	.9	.66	1.7	.45
methylpyrene	-	-	-	-	-
benzo (a) anthracene	-	-	-	-	-
chrysene	-	-	-	.54	-
benzo (e) pyrene	-	-	-	-	-
benzo (a) pyrene	-	-	-	-	-
perylene	-	-	-	-	-
TOTAL	1400.6	374.4	62.2	1874.7	39.

TABLE 9

EMISSION OF PAH AT LAMEQUE PEAT BURNER
EXPRESSED AS MICROGRAMS PER POUND OF DRY FUEL

COMPUTER MATCHES - MARTIME FOREST RANGER SCHOOL
SAMPLE: M3

SCAN #	COMPOUND	FIT
18	ethyl benzenes	915
116	dimethoxy benzenes	769
172	methoxy propenyl phenol	737
430	substituted naphthopyranone	444
501	phenanthrol	556
535	methyl pyrene	298
574	substituted phenanthrol	838
582	substituted anthracenedione	812
651	substituted podocarpenol	475
697	dioctyl phthalate	779

TABLE 10

COMPUTER MATCHES - MARITIME FOREST RANGER SCHOOL

SAMPLE: M4

SCAN #	COMPOUND	FIT
20	ethyl benzene	915
35	methoxy benzene	919
52	silyl compound	921
60	benzofuran	711
65	methoxy methyl benzene	892
74	substituted benzene	551
82	propenoic ester	800
94	phenyl propenal	623
108	methyl indene	865
116	dimethoxy benzene	668
163	substituted phenol	621
191	dihydro acenanphthylene	935
196	methyl biphenyl	561
225	biphenylene	727
252	dibenzofuran	462
280	fluorene	759
298	methyl dibenzofuran	825
325	methyl fluorene	788
362	phenanthrene	899
420	substituted phenanthrene	613
478	pyrene	902
488	fluoranthene	806
501	pyrene	791
538	tetramethyl phenanthrene	616
578	substituted phenanthiol	854
586	substituted anthracenedione	807
633	benzofluoranthene	903
666	benzophenanthrene	829
981	saturated hydrocarbon	659

TABLE 11

COMPUTER MATCHES - MARTIME FOREST RANGER SCHOOL
SAMPLE M6

SCAN #	COMPOUND	FIT
19	ethyl benzene	923
51	silyl compound	917
58	benzofuran	714
64	ethyl hexanol	687
79	propenoic ester	791
97	silyl compound	694
117	naphthalene	898
122	substituted phenol	676
134	silyl compound	444
184	biphenyl	542
190	methyl biphenyl	803
215	silyl compound	483
224	methyl biphenyl	840
228	silyl compound	401
241	dibenzofuran	848
269	fluorene	509
286	silyl compound	481
297	phenyl benzoate	968
324	methyl phenyl benzoate	892
355	phenanthrene	331
388	bromo octane	621
424	bromo octane	634
450	bromo octane	477
532	bromo octane	602
824	octadecanoic ester	491

TABLE 12

COMPUTER MATCHES - MARITIME FOREST RANGER SCHOOL
SAMPLE: M7

SCAN #	COMPOUND	FIT
18	ethyl benzene	915
97	silyl compound	708
105	dimethyl ethyl benzene	581
118	naphthalene	834
155	methyl naphthalene	953
201	dimethyl naphthalene	938
210	dimethyl naphthalene	920
215	dimethyl naphthalene	515
224	methyl biphenyl	756
241	dibenzofuran	708
252	trimethyl naphthalene	863
259	trimethyl naphthalene	804
270	fluorene	525
285	dimethyl biphenyl	565
296	phenyl bernzoate	791
418	methyl phenanthrene	551
450	substituted naphthalene	770
468	substituted indacene dione	436
978	saturated hydrocarbon	653

TABLE 13

COMPUTER MATCHES - MARITIME FOREST RANGER SCHOOL
SAMPLE: M8

SCAN #	COMPOUND	FIT
21	ethyl benzene	920
30	dimethyl benzene	735
45	ethyl hexanal	820
52	phenol	696
61	benzodioxole	801
67	nonanol	767
74	dimethyl phenol	704
81	ethyl hexanol	550
87	methoxy phenol	938
102	dimethyl phenol	556
109	methoxy benzaldehyde	713
118	substituted phenol	689
127	propenoic ester	559
156	bromo octane	679
187	biphenyl	657
196	dimethyl benzofuranone	526
219	silyl compound	301
232	methyl biphenyl	527
244	dibenzofuran	851
273	fluorene	392
300	phenyl benzoate	961
327	methyl phenyl benzoate	755
358	bromo octane	396
392	bromo octane	575
406	bromo octane	650
427	bromo octane	591
454	bromo octane	566
462	bromo octane	609
477	fluoranthene	508
494	bromo octane	314
534	bromo octane	683
982	saturated hydrocarbon	642

TABLE 14

COMPUTER MATCHES - MARITIME FOREST RANGER SCHOOL
SAMPLE: M9

SCAN #	COMPOUND	FIT
19	ethyl benzene	923
57	silyl compound	803
73	silyl compound	586
80	ethyl hexanol	849
85	methoxy phenol	829
104	silyl compound	622
124	silyl compound	652
156	silyl compound	687
175	silyl compound	547
185	biphenyl	825
192	methyl biphenyl	799
218	silyl compound	516
233	di-tert butyl methyl phenol	896
242	di-benzofuran	797
270	fluorene	734
288	silyl compound	544
297	phenyl benzoate	906
356	silyl compound	541
370	silyl compound	651
389	bromo octane	603
420	silyl compound	470
425	bromo octane	622
451	bromo octane	557
481	silyl compound	490
540	silyl compound	473
702	silyl compound	443
827	silyl compound	460
1000	silyl compound	441

TABLE 15

COMPUTER MATCHES - MARITIME FOREST RANGER SCHOOL
SAMPLE: M10

SCAN #	COMPOUND	FIT
20	ethyl benzene	887
55	silyl compound	867
71	silyl compound	653
79	ethyl hexanol	840
100	silyl compound	677
118	naphthalene	880
123	silyl compound	647
155	silyl compound	702
175	silyl compound	619
191	methyl biphenyl	838
217	silyl compound	554
230	silyl compound	707
241	dibenzofuran	630
287	silyl compound	559
295	silyl compound	448
300	silyl compound	623
324	methyl phenyl benzoate	582
356	silyl compound	589
420	silyl compound	480
441	silyl compound	334
450	phenyl methyl naphthalene	638
481	silyl compound	524
540	silyl compound	483
611	silyl compound	480
702	silyl compound	464
826	silyl compound	430
998	silyl compound	460

TABLE 16

COMPUTER MATCHES - MARITIME FOREST RANGER SCHOOL
SAMPLE: M11

SCAN #	COMPOUND	FIT
20	ethyl benzene	925
44	ethyl hexanol	669
49	benzaldehyde	931
73	dimethyl phenol	652
81	decanol	661
88	methoxy phenol	895
101	acetic ester	764
108	methoxy benzaldehyde	675
118	dimethoxy benzene	730
128	propanoic ester	554
146	dihydroxy acetophenone	813
155	ethyl methyl heptane	898
174	substituted phenol	865
190	methyl tridecane	742
242	dibenzofuran	811
258	deconal	609
298	phenyl benzoate	947
315	benzoic ester	556
357	phenanthrene	428
420	silyl compound	499
474	methyl heptadecanol	375
535	tetramethyl phenanthrene	653
555	naphthalene carboxylic acid	622

TABLE 17

COMPUTER MATCHES - MARITIME FOREST RANGER SCHOOL
SAMPLE: M12

SCAN #	COMPOUND	FIT
18	ethyl benzene	778
24	heptanone	907
68	ethyl hexanol	740
75	hydroxy benzaldehyde	759
85	decanol	532
92	methoxy phenol	891
104	acetic ester	734
111	methoxy benzaldehyde	741
132	substituted phenol	661
157	ethyl methyl heptane	834
209	tert butyl acetophenone	472
299	phenyl benzoate	596
358	bromo octane	393
391	bromo octane	600
426	bromo octane	592
450	bromo octane	436
460	bromo octane	592
480	silyl compound	449
532	bromo octane	656
539	silyl octane	417
664	di octyl phthalate	332
699	di octyl phthalate	806
979	saturated hydrocarbon	679

TABLE 18

COMPUTER MATCHES - MARITIME FOREST RANGER SCHOOL
SAMPLE: M13

SCAN #	COMPOUND	FIT
19	ethyl benzene	632
27	heptanone	892
53	heptanol	633
63	ethyl hexanol	666
83	dimethyl octanol	756
105	acetic ester	705
113	ethyl benzoate	789
127	propenoic ester	858
158	octyl ether	618
181	cycohexanedione	712
191	dimethyl heptane	569
251	pyrrolidine propionamide	690
298	phenyl benzoate	699
338	fluorenone	810
357	tetradecanoic acid	441
390	bromo octane	628
420	silyl compound	505
425	ethyl methyl heptane	687
451	phenyl methyl naphthalene	401
480	silyl compound	458
512	hexadecyl acetate	743
540	silyl compound	437
611	silyl compound	464
700	dioctyl phthalate	812

TABLE 19

COMPUTER MATCHES - PAPER MILL
SAMPLE: M14

SCAN #	COMPOUND	FIT
18	ethyl benzene	935
65	ethyl hexanol	875
79	ethyl hexanol	794
98	silyl compound	724
119	naphthalene	943
134	butyl cyclohexane	436
153	silyl compound	706
185	biphenyl	901
192	methyl biphenyl	882
218	silyl compound	567
226	methyl biphenyl	910
230	methyl biphenyl	533
281	phenyl benzenamine	859
288	silyl compound	508
356	silyl compound	323
390	bromo octane	621
453	bromo octane	559
493	bromo octane	323
534	bromo octane	609
830	octyl octadecanoate	608

TABLE 20

COMPUTER MATCHES - PAPER MILL
SAMPLE: M15

SCAN #	COMPOUND	FIT
60	ethyl hexanol	683
78	silyl compound	725
114	butyl cyclohexane	449
133	silyl compound	701
166	biphenyl	480
198	silyl compound	556
262	phenyl benzenamine	929
268	silyl compound	575
277	phenyl benzoate	734
295	silyl compound	340
337	silyl compound	474
373	isopropyl benzenamine	778
401	silyl compound	494
433	phenanthrene carboxaldehyde	659
461	silyl compound	443
478	pyrene	936
516	tetramethyl phenanthrene	814
520	silyl compound	439
537	substituted dihydrobenzofuran	606
580	eicosane	820

TABLE 21

COMPUTER MATCHES - PAPER MILL
SAMPLE: M16

SCAN #	COMPOUND	FIT
20	ethyl benzene	910
52	silyl compound	904
97	silyl compound	715
133	substituted morpholine	410
153	silyl compound	698
176	silyl compound	540
191	methyl biphenyl	871
217	silyl compound	561
230	silyl compound	542
288	silyl compound	545
314	silyl compound	388
356	silyl compound	511
421	silyl compound	439
431	nitro diphenyl amine	857
453	phenanthrenecarboxaldehyde	637
472	saturated hydrocarbon	463
481	silyl compound	467
498	pyrene	928
535	tetramethyl phenanthrene	525
540	silyl compound	434
611	silyl compound	454
664	octyl ether	493
702	silyl compound	437
827	substituted benzopyrene	372

TABLE 22

COMPUTER MATCHES - PAPER MILL
SAMPLE: M17

SCAN #	COMPOUND	FIT
20	ethyl benzene	932
50	silyl compound	930
65	trimethyl benzene	907
80	methyl propyl benzene	917
96	silyl compound	722
105	dimethyl ethyl benzene	751
117	naphthalene	753
132	butyl cyclohexane	453
152	silyl compound	656
175	silyl compound	325
190	propenyl naphthalene	889
201	dimethyl naphthalene	928
216	silyl compound	567
224	methyl biphenyl	890
229	silyl compound	426
259	trimethyl naphthalene	880
281	phenyl benzenamine	921
312	silyl compound	415
355	silyl compound	547
420	silyl compound	542
451	phenthrene carboxaldehyde	522
480	silyl compound	458
497	pyrene	934
534	tetramethyl phenanthrene	712
539	silyl compound	445
609	silyl compound	456
699	silyl compound	426
974	saturated hydrocarbon	659

TABLE 23

COMPUTER MATCHES - PAPER MILL
SAMPLE: M18

SCAN #	COMPOUND	FIT
19	ethyl benzene	929
51	silyl compound	915
97	silyl compound	715
118	naphthalene	918
133	dipentyl heptadecane	342
153	silyl compound	698
191	propenyl naphthalene	909
217	silyl compound	566
225	methyl biphenyl	910
229	methyl biphenyl	552
245	silyl compound	464
288	silyl compound	516
294	silyl compound	708
313	silyl compound	434
356	silyl compound	538
380	silyl compound	448
421	silyl compound	622
430	nitro diphenyl amine	878
452	phenanthrenecarboxaldehyde	673
480	silyl compound	458
497	pyrene	925
534	tetramethyl phenanthrene	463
539	silyl compound	442
610	silyl compound	455
701	silyl compound	450
825	silyl compound	443
976	saturated hydrocarbon	621

TABLE 24

COMPUTER MATCHES - PAPER MILL
SAMPLE: M19

SCAN #	COMPOUND	FIT
18	ethyl benzene	913
51	silyl compound	930
65	diethyl benzene	862
96	silyl compound	720
105	dimethyl ethyl benzene	733
118	naphthalene	860
132	butyl cyclohexane	508
151	silyl compound	684
190	propenyl naphthalene	828
216	silyl compound	564
281	phenyl benzenamine	913
287	silyl compound	548
355	silyl compound	490
391	isopropyl phenylamine	790
419	silyl compound	489
431	substituted phenanthrenone	518
451	phenanthrenecarboxaldehyde	662
460	substituted naphthalenedione	579
479	silyl compound	456
496	pyrene	915
538	silyl compound	439
556	substituted benzofuran	590

TABLE 25

COMPUTER MATCHES - LAMEQUE
SAMPLE: 01

SCAN #	COMPOUND	FIT
20	ethyl benzene	915
52	silyl compound	918
57	trimethyl benzene	919
79	ethyl hexanol	874
97	silyl compound	726
118	napthalene	941
152	silyl compound	648
184	biphenyl	901
191	methyl biphenyl	900
201	dimethyl napthalene	914
216	silyl compound	538
225	methyl biphenyl	909
229	methyl biphenyl	738
253	trimethyl naphthalene	902
287	silyl compound	524
305	dimethyl isopiopyl naphthalene	794
355	silyl compound	435
420	silyl compound	510
451	bromo-octanend	591
480	silyl compound	469
539	silyl compound	436
610	silyl compound	463
701	silyl compound	462
825	silyl compound	406

TABLE 26

COMPUTER MATCHES - LAMEQUE
SAMPLE: 02

SCAN #	COMPOUND	FIT
21	ethyl benzene	922
45	ethyl hexanol	797
80	dimethyl octanol	783
98	silyl compound	711
106	dimethyl ethyl benzene	598
125	propenoic ester	651
141	chloro dodecane	401
154	silyl compound	710
192	methyl biphenyl	903
219	silyl compound	559
225	methyl biphenyl	904
265	dimethyl undecane	568
287	silyl compound	487
314	benzoate ester	604
356	silyl compound	522
389	methyl heptadecane	424
419	silyl compound	500
449	substituted napthalene	859
471	decyl ether	467

TABLE 27

COMPUTER MATCHES - LAMEQUE
SAMPLE: 03

SCAN	COMPOUND	FIT
18	ethyl benzene	933
51	silyl compound	926
79	ethyl hexanol	673
96	silyl compound	707
152	silyl compound	699
175	silyl compound	518
190	methyl biphenyl	887
216	silyl compound	544
224	methyl biphenyl	870
228	silyl compound	362
286	silyl compound	511
294	silyl compound	379
313	benzoate ester	566
354	silyl compound	489
418	silyl compound	496
448	substituted naphthalene	810

TABLE 28

COMPUTER MATCHES - LAMEQUE
SAMPLE: 04

SCAN	COMPOUND	FIT
16	ethyl benzene	904
50	silyl compound	915
58	benzofuran	794
79	ethyl hexanol	762
90	phenyl propenal	833
97	silyl compound	670
105	tetramethyl benzene	884
118	napthalene	727
125	dimethyl benzofuran	584
152	silyl compound	684
162	methyl naphthalene	675
175	silyl compound	413
184	biphenyl	917
191	methyl biphenyl	883
203	dimethyl naphthalene	846
209	dimethyl naphthalene	504
216	silyl compound	480
225	methyl biphenyl	821
229	methyl biphenyl	585
242	dibenzofuran	889
259	trimethyl naphthalene	931
270	fluorene	553
287	silyl compound	530
333	substituted naphthalene	641
356	phenanthrene	624
406	methyl phenanthrene	870
419	silyl compound	456

TABLE 29

COMPUTER MATCHES - LAMEQUE
SAMPLE: 05

SCAN	COMPOUND	FIT
20	ethyl benzene	918
50	silyl compound	910
95	silyl compound	727
150	silyl compound	679
173	silyl compound	415
196	silyl compound	545
285	silyl compound	505
353	silyl compound	475
418	silyl compound	511
694	dioctyl phthalate	793
968	saturated hydrocarbon	679

TABLE 30

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FIGURE 1.

Reconstructed Ion Chromatogram

Sample - M3

Location - Maritime Forest Ranger School

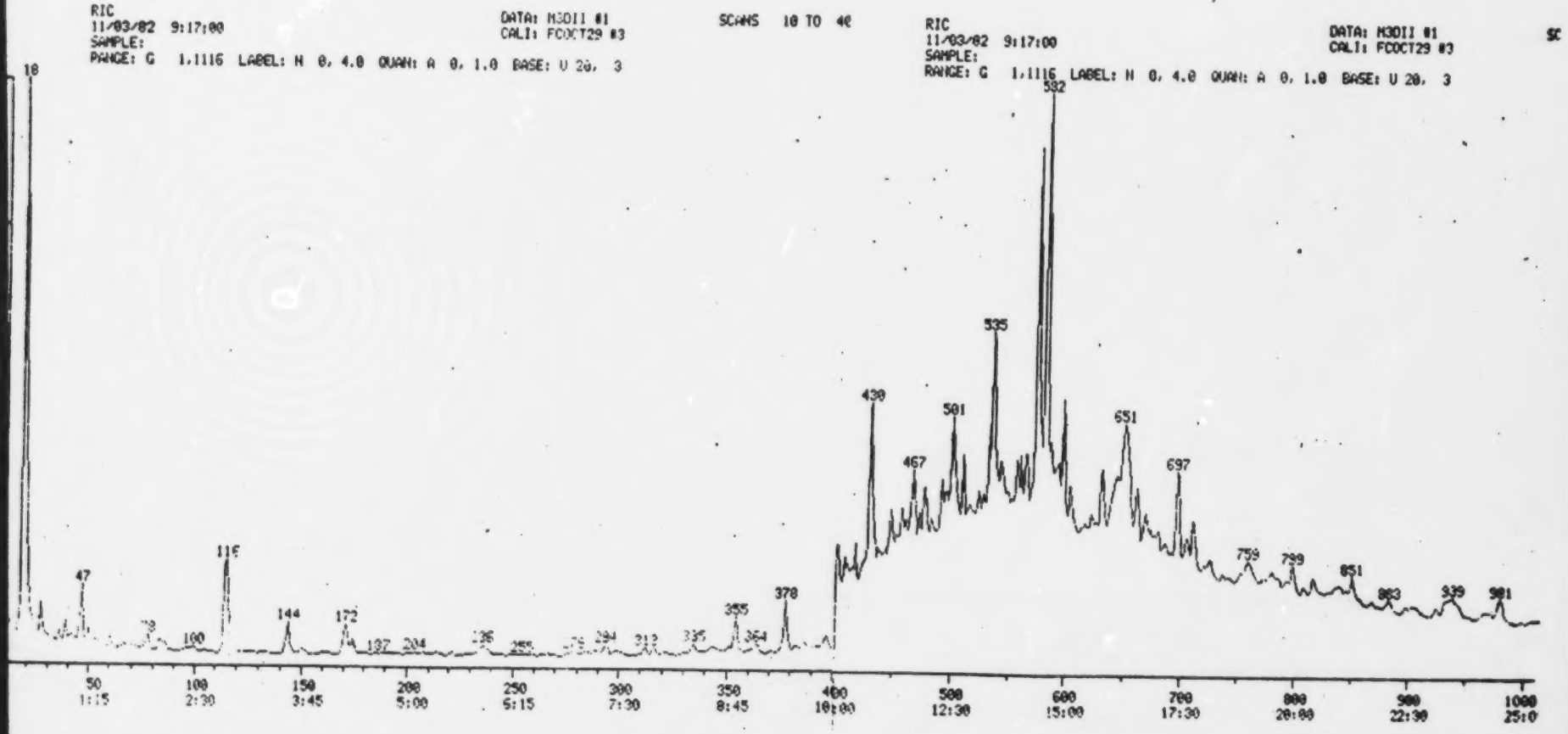

FIGURE 2.

Reconstructed Ion Chromatogram

Sample - M4

Location - Maritime Forest Ranger School

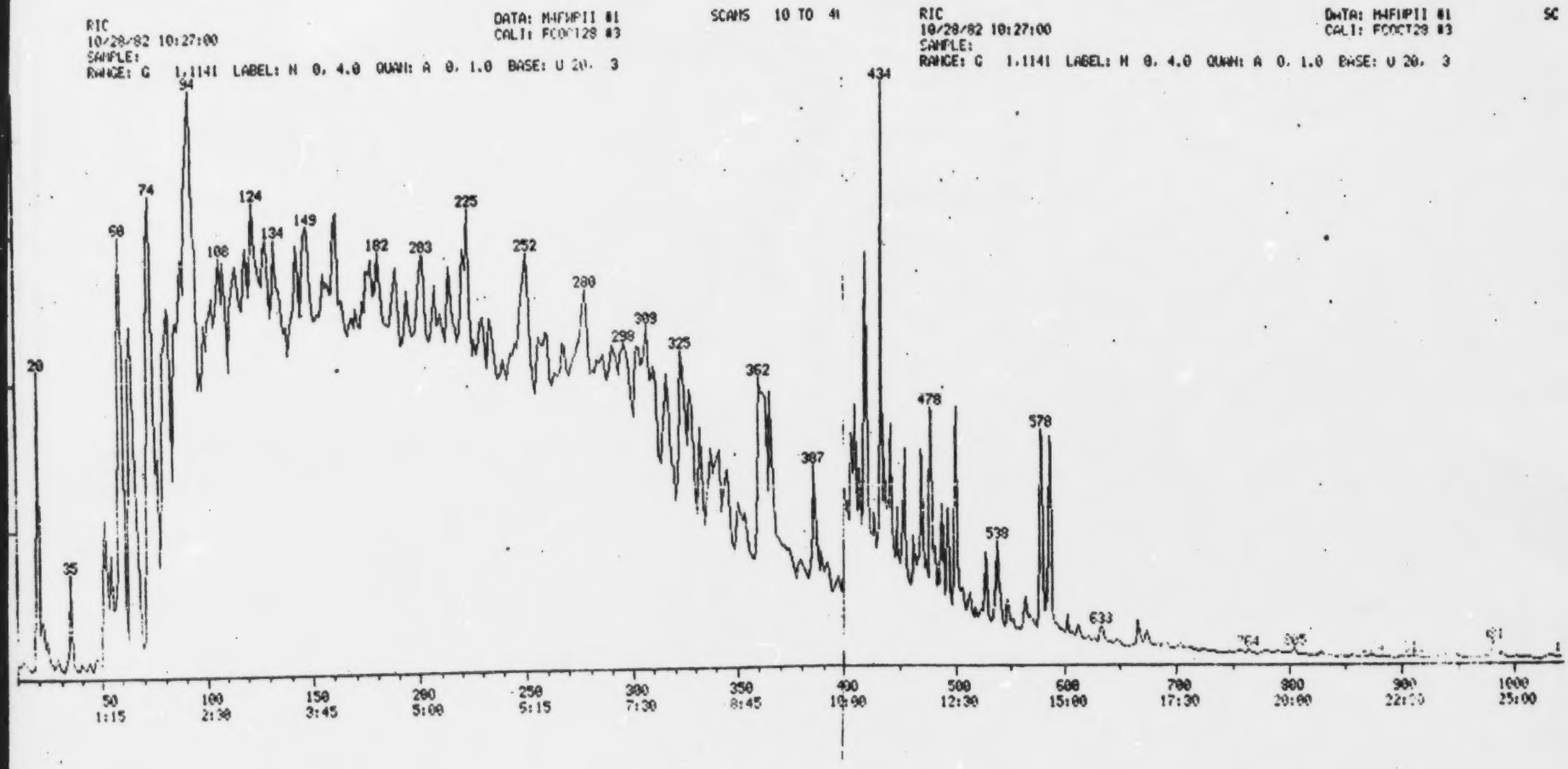

FIGURE 3.

Reconstructed Ion Chromatogram

Sample - M6

Location - Maritime Forest Ranger School

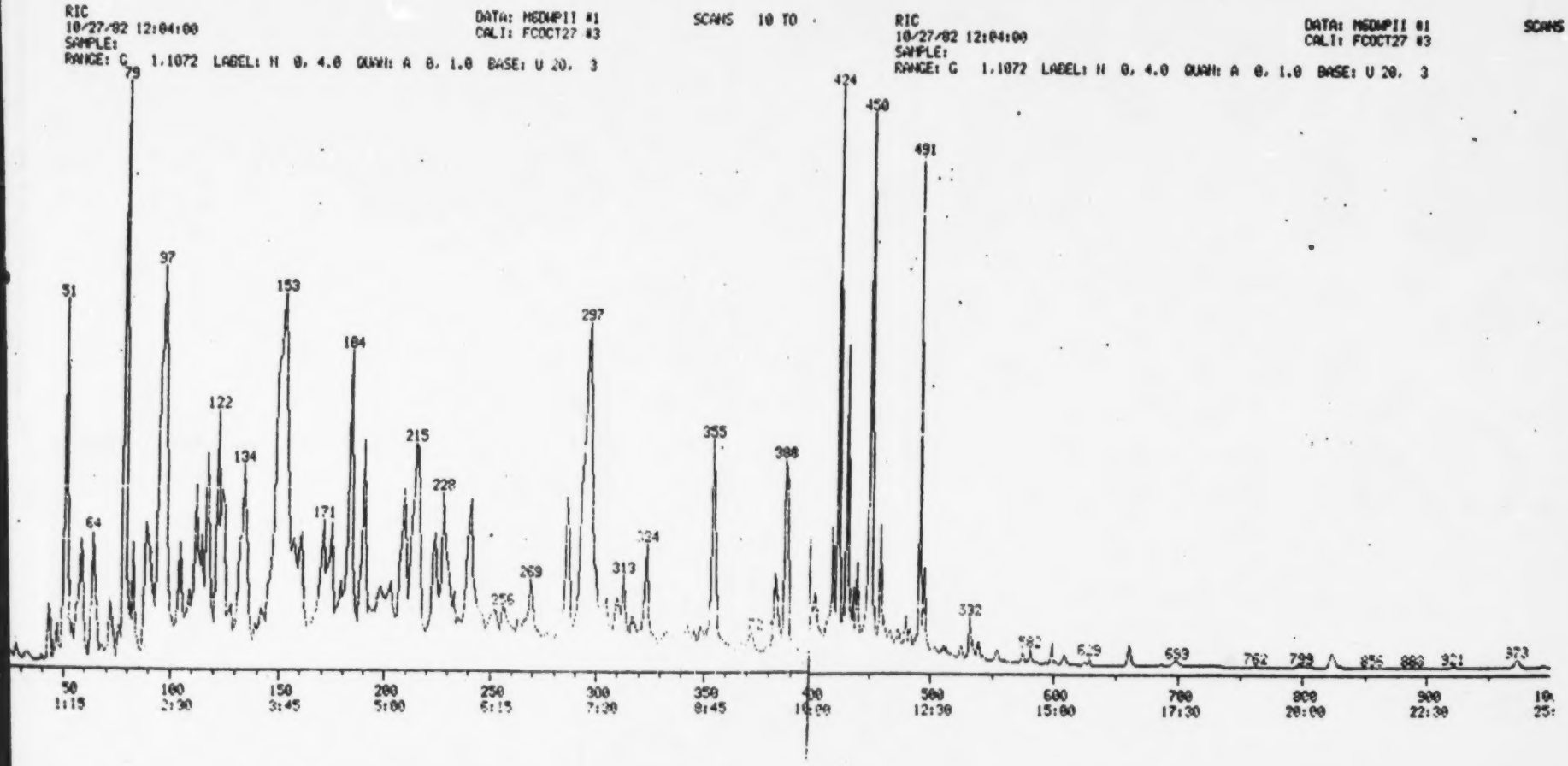

FIGURE 4.

Reconstructed Ion Chromatogram

Sample - M7

Location - Maritime Forest Ranger School

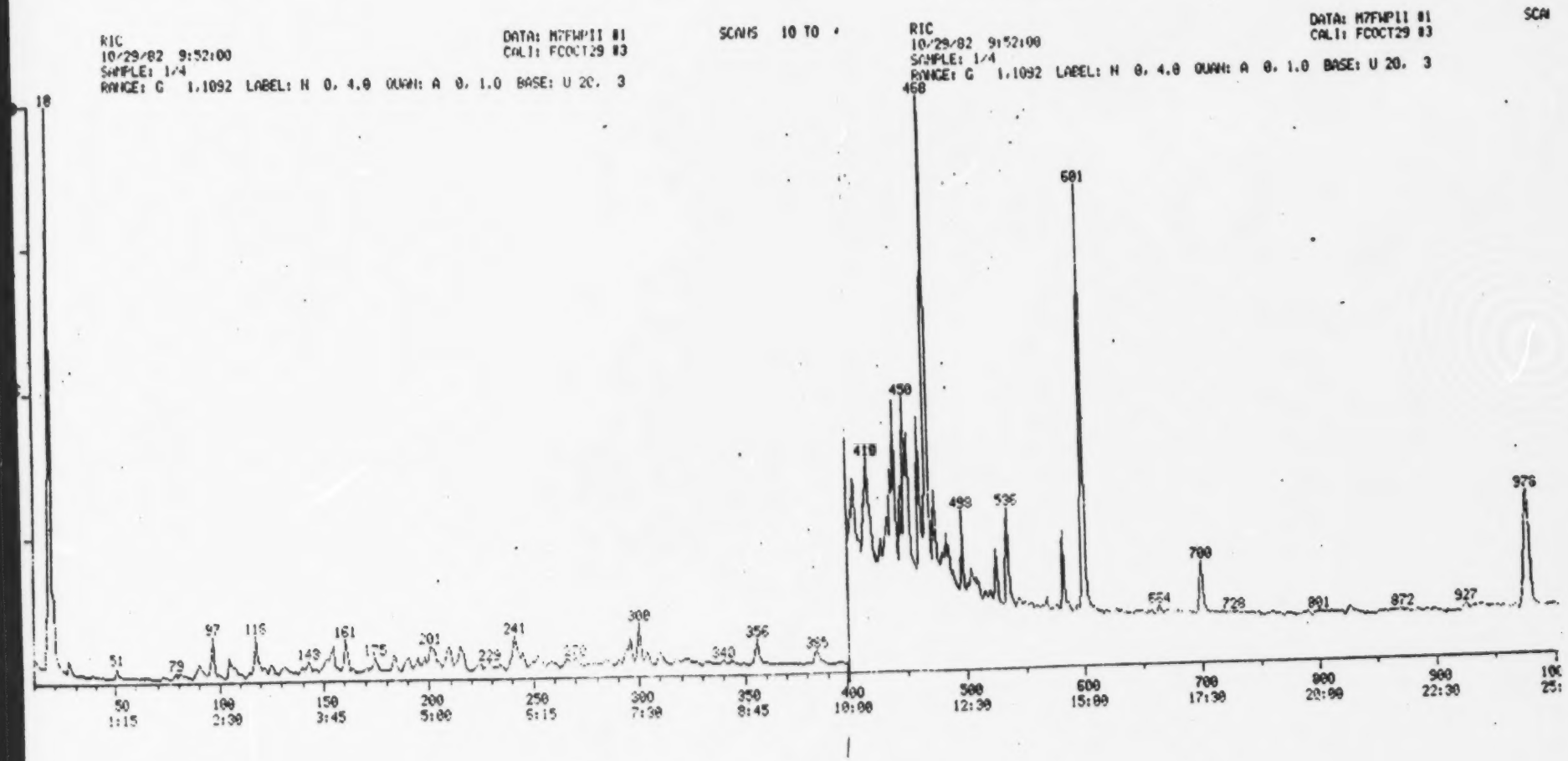

FIGURE 5.

Reconstructed Ion Chromatogram

Sample - M8

Location - Maritime Forest Ranger School

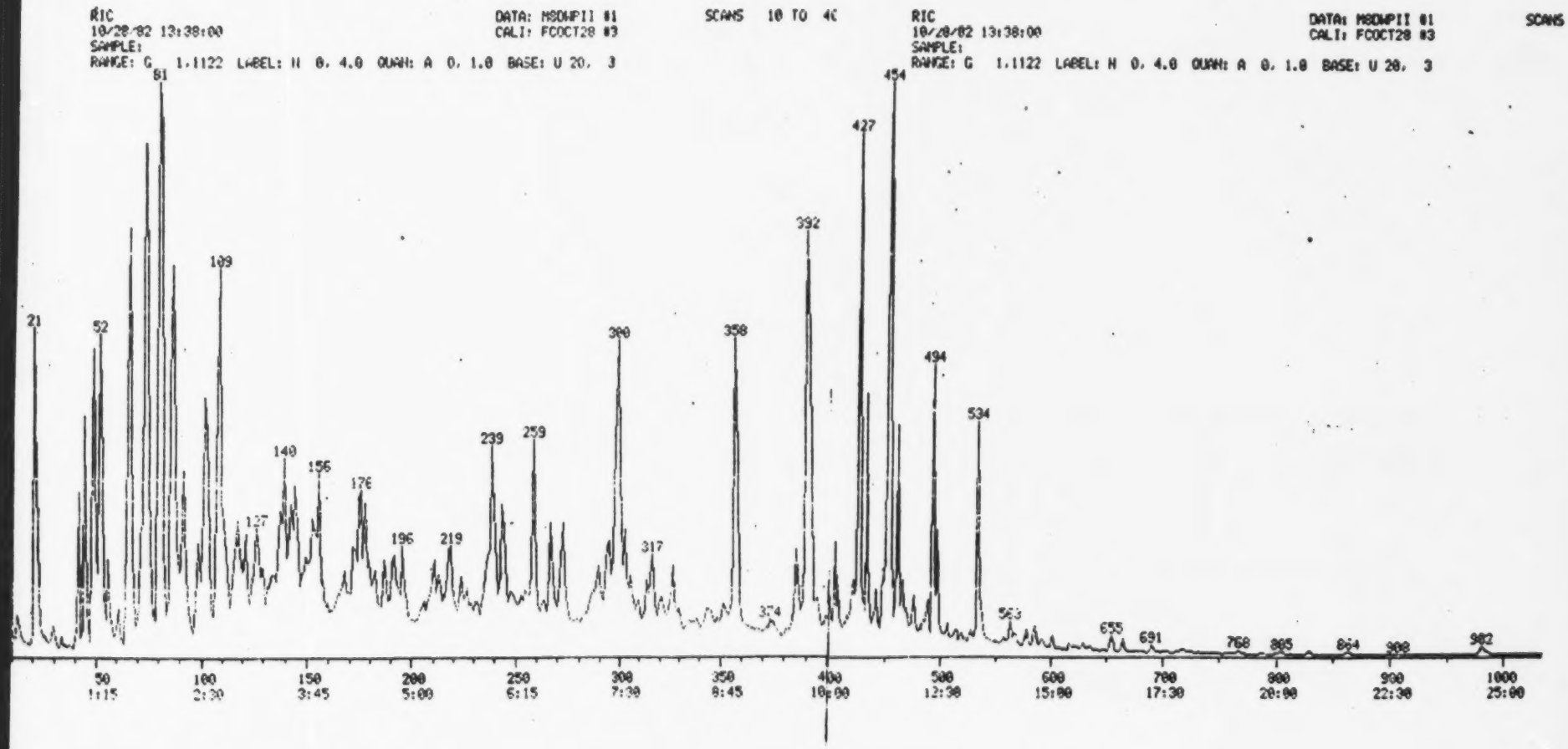

FIGURE 6.

Reconstructed Ion Chromatogram

Sample - M9

Location - Maritime Forest Ranger School

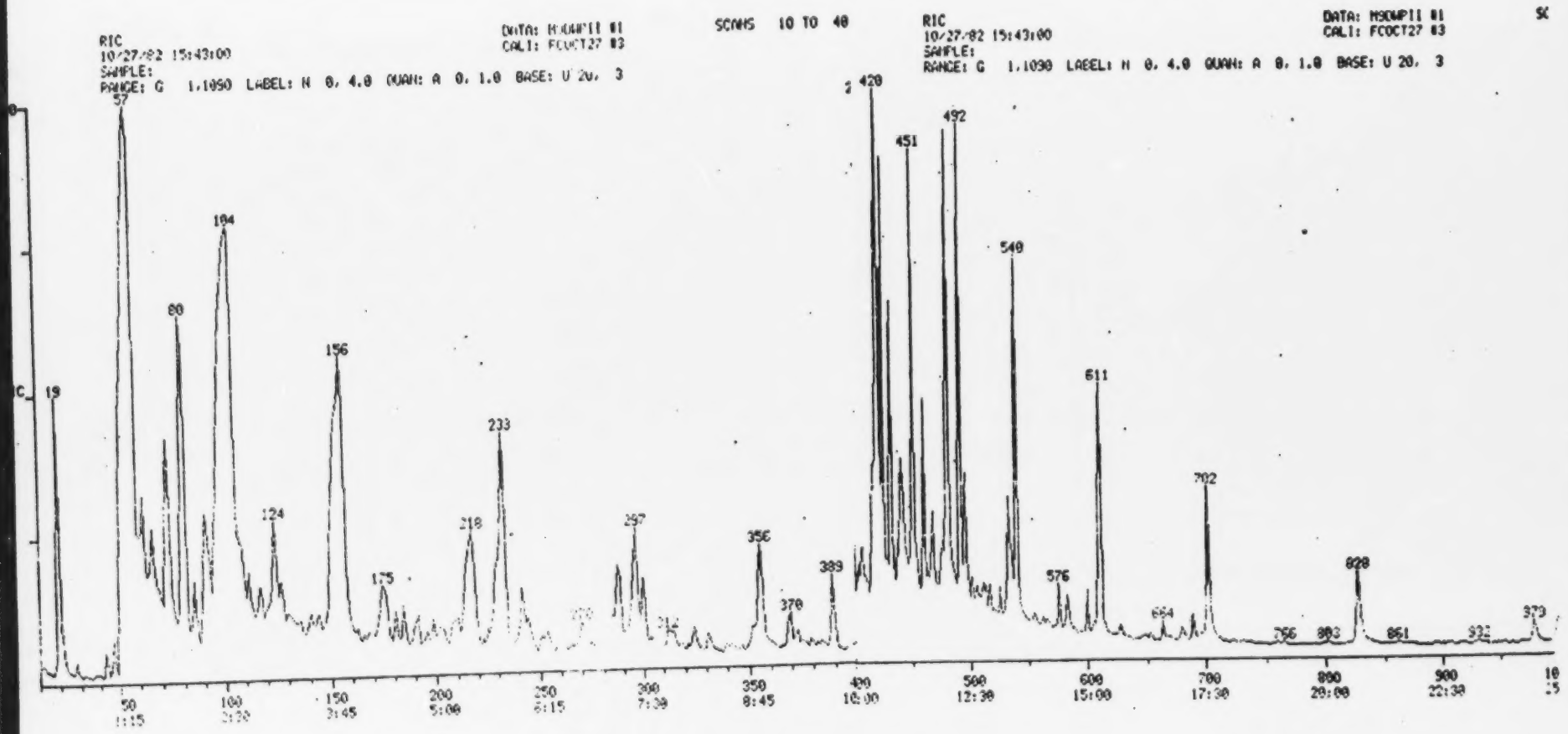

FIGURE 7.

Reconstructed Ion Chromatogram

Sample - M10

Location - Maritime Forest Ranger School

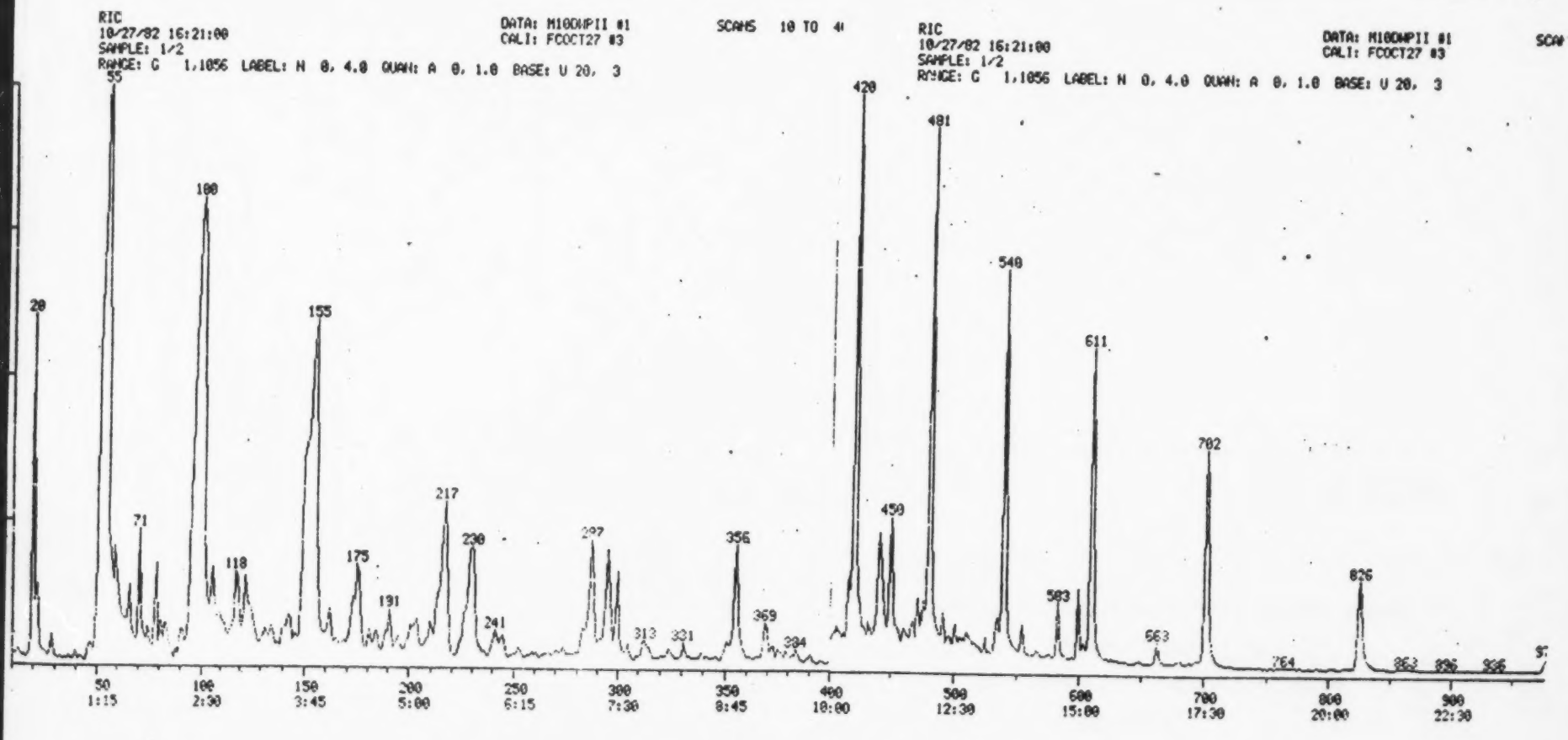

FIGURE 8.

Reconstructed Ion Chromatogram

Sample - M11

Location - Maritime Forest Ranger School

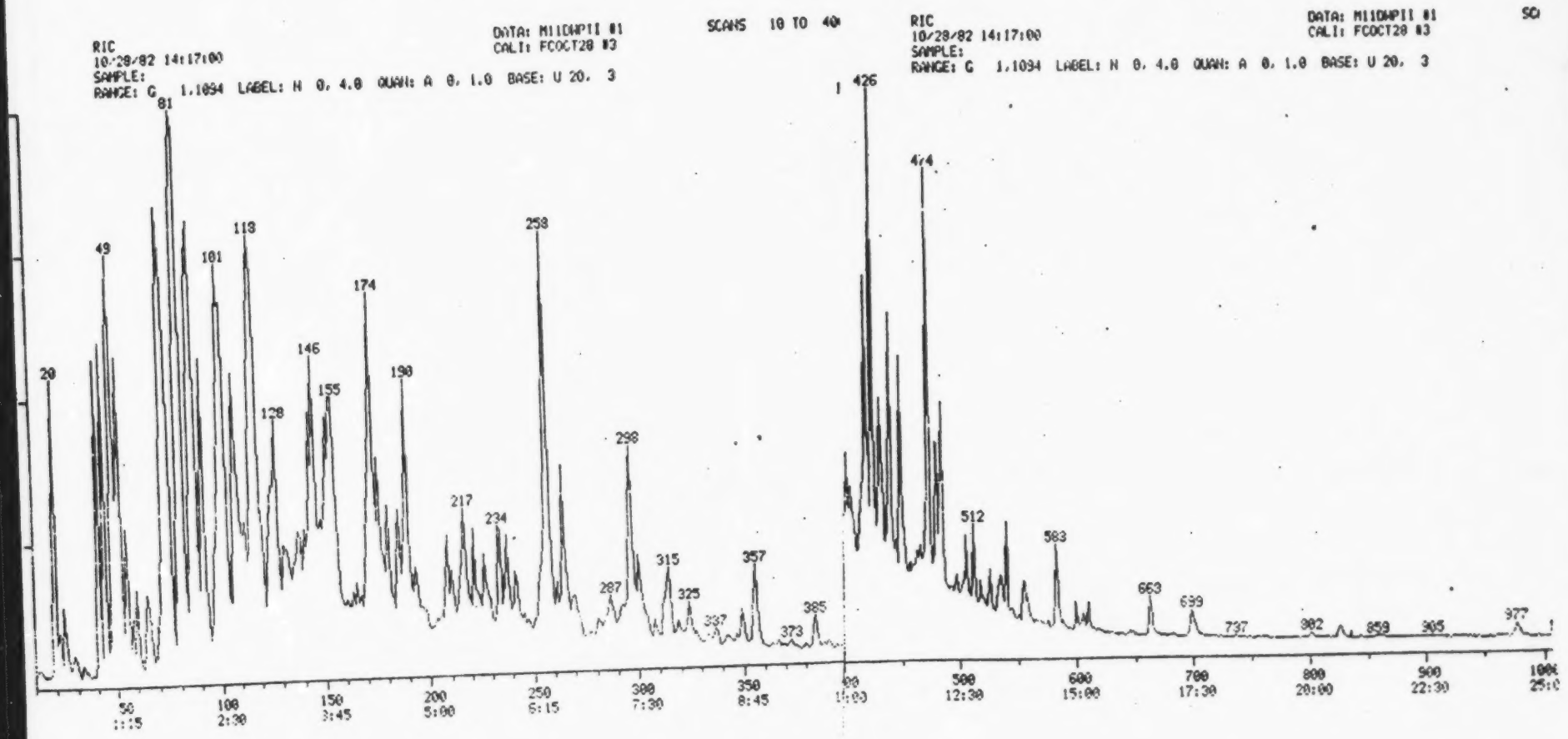

FIGURE 9.

Reconstructed Ion Chromatogram

Sample - M12

Location - Maritime Forest Ranger School

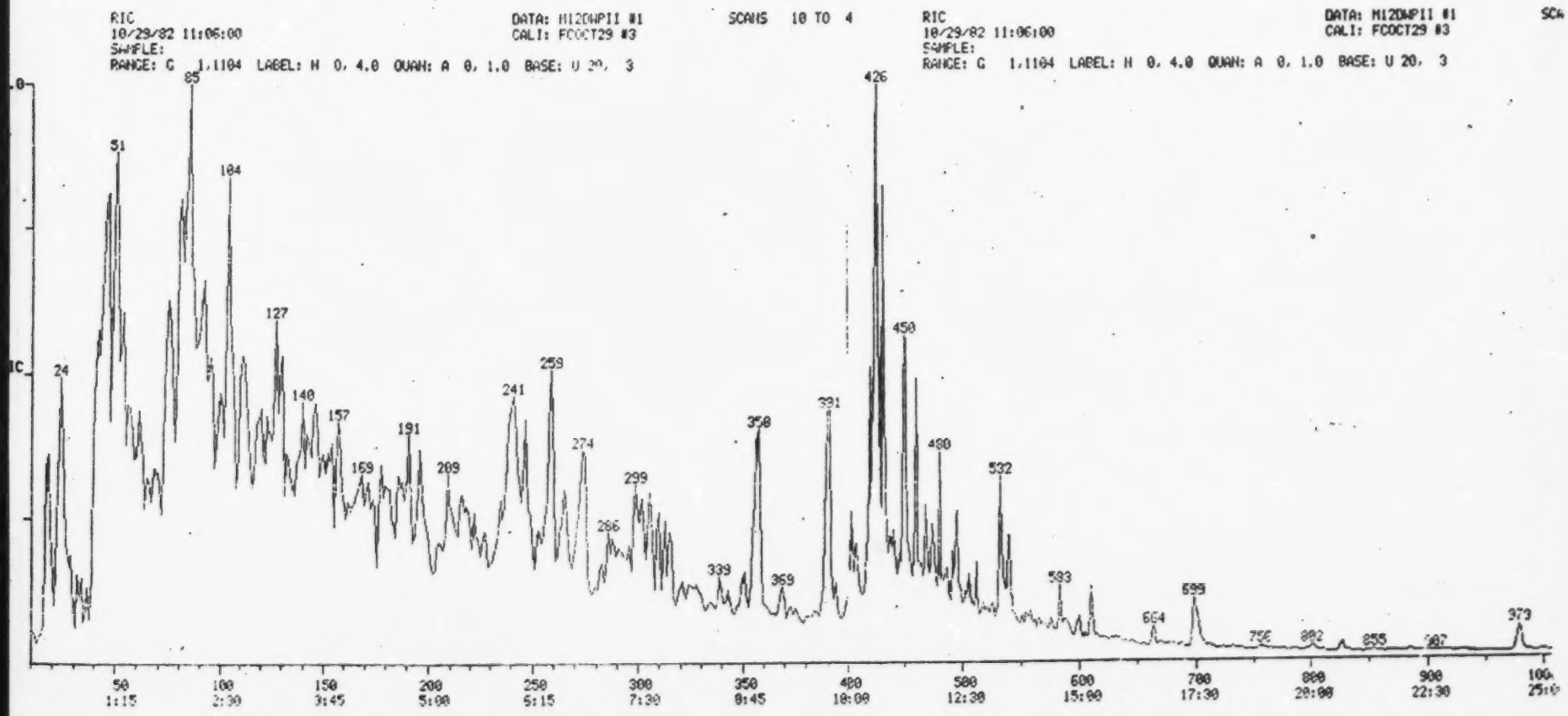

FIGURE 10.

Reconstructed Ion Chromatogram

Sample - M13

Location - Maritime Forest Ranger School

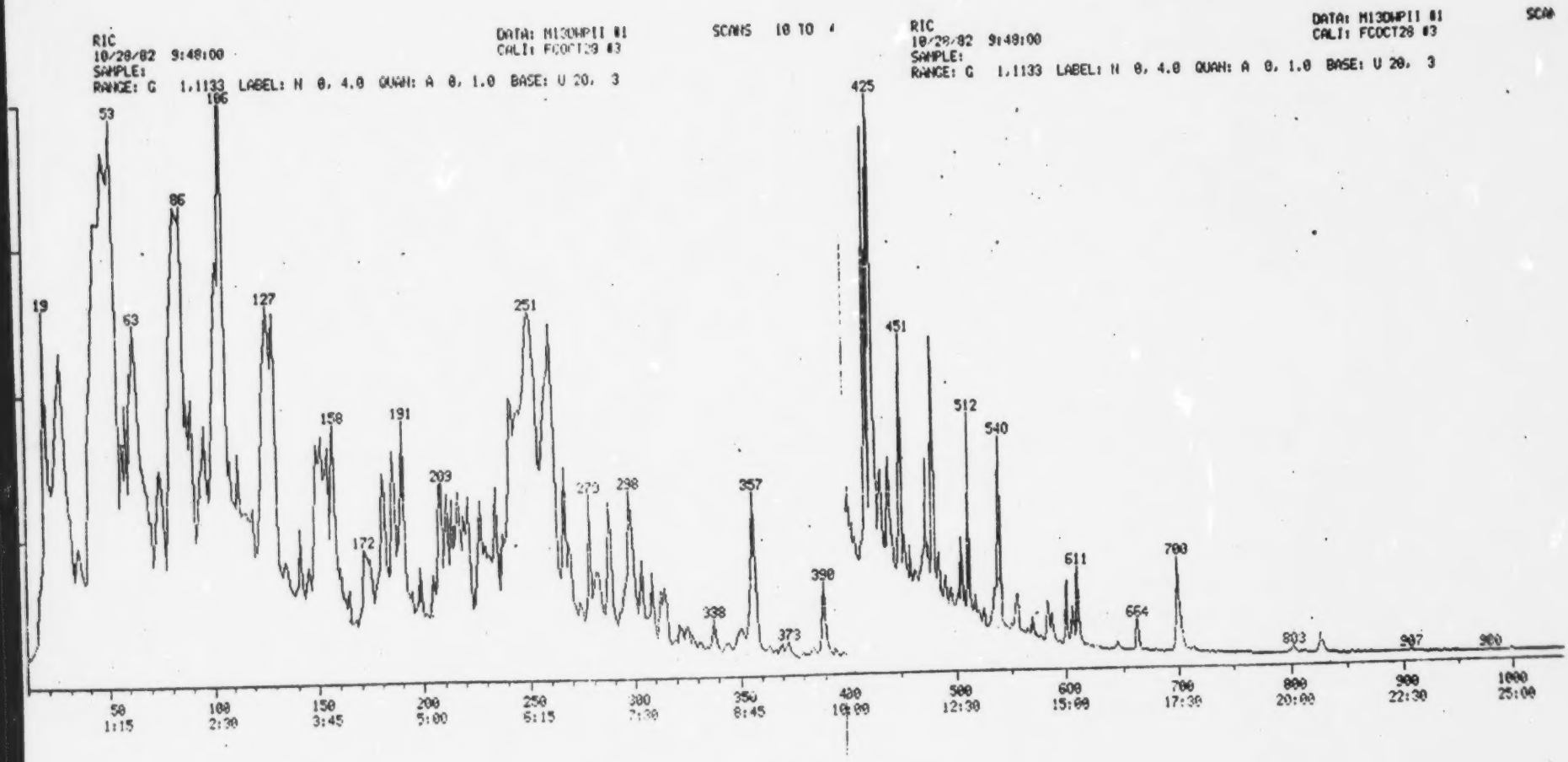

FIGURE 11.

Reconstructed Ion Chromatogram

Sample - M14

Location - Pulp Mill

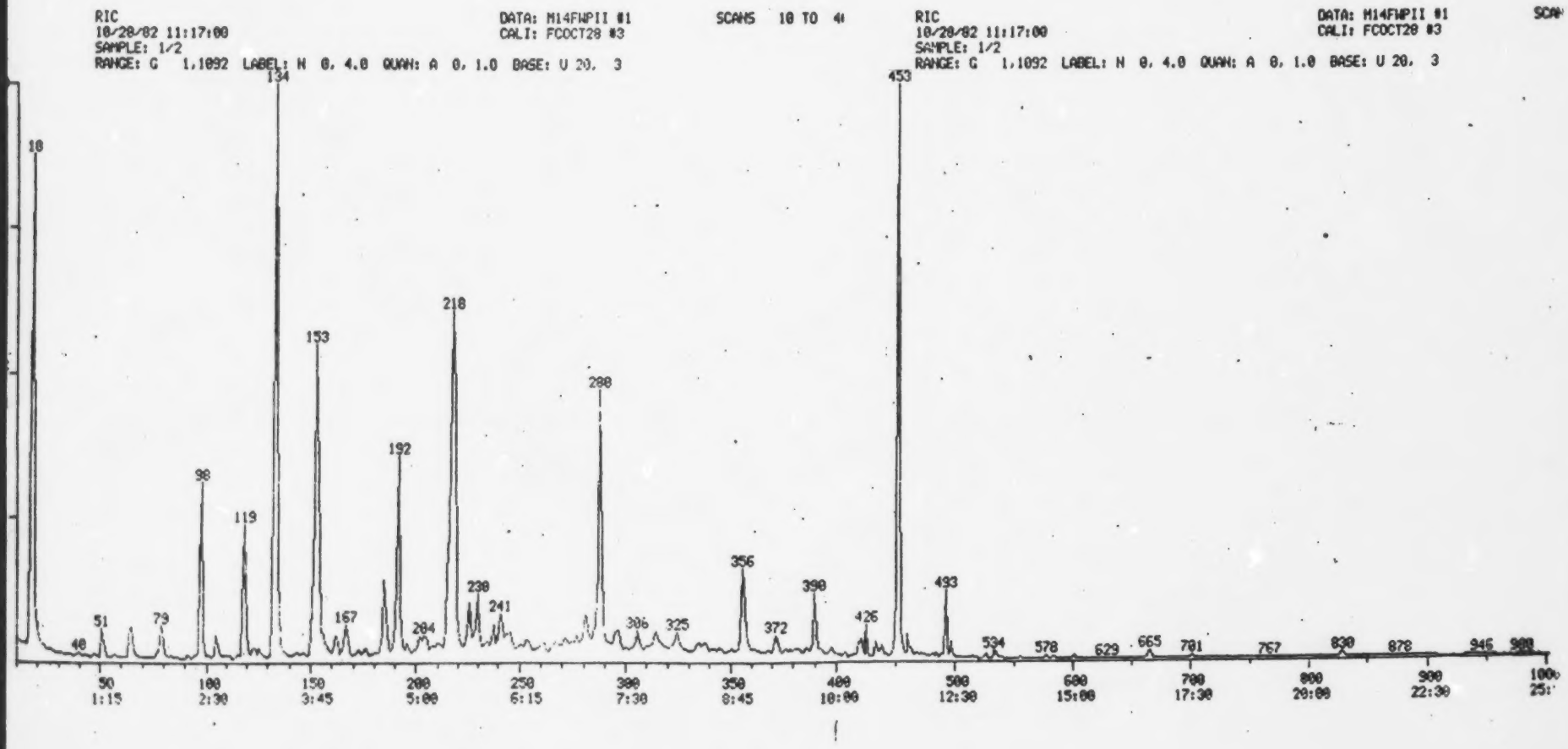

FIGURE 12.

Reconstructed Ion Chromatogram

Sample - M15

Location - Pulp Mill

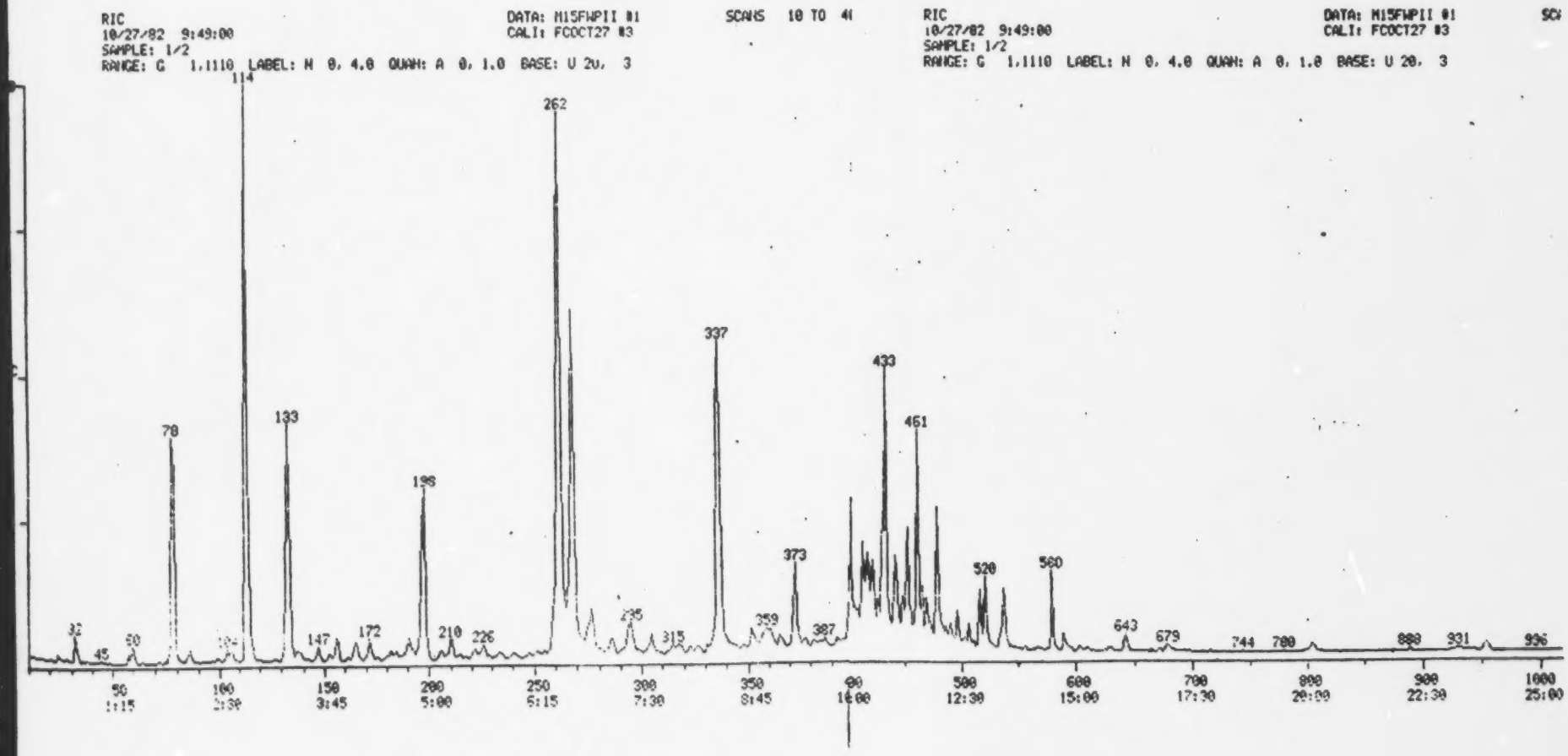

FIGURE 13.

Reconstructed Ion Chromatogram

Sample - M16

Location - Pulp Mill

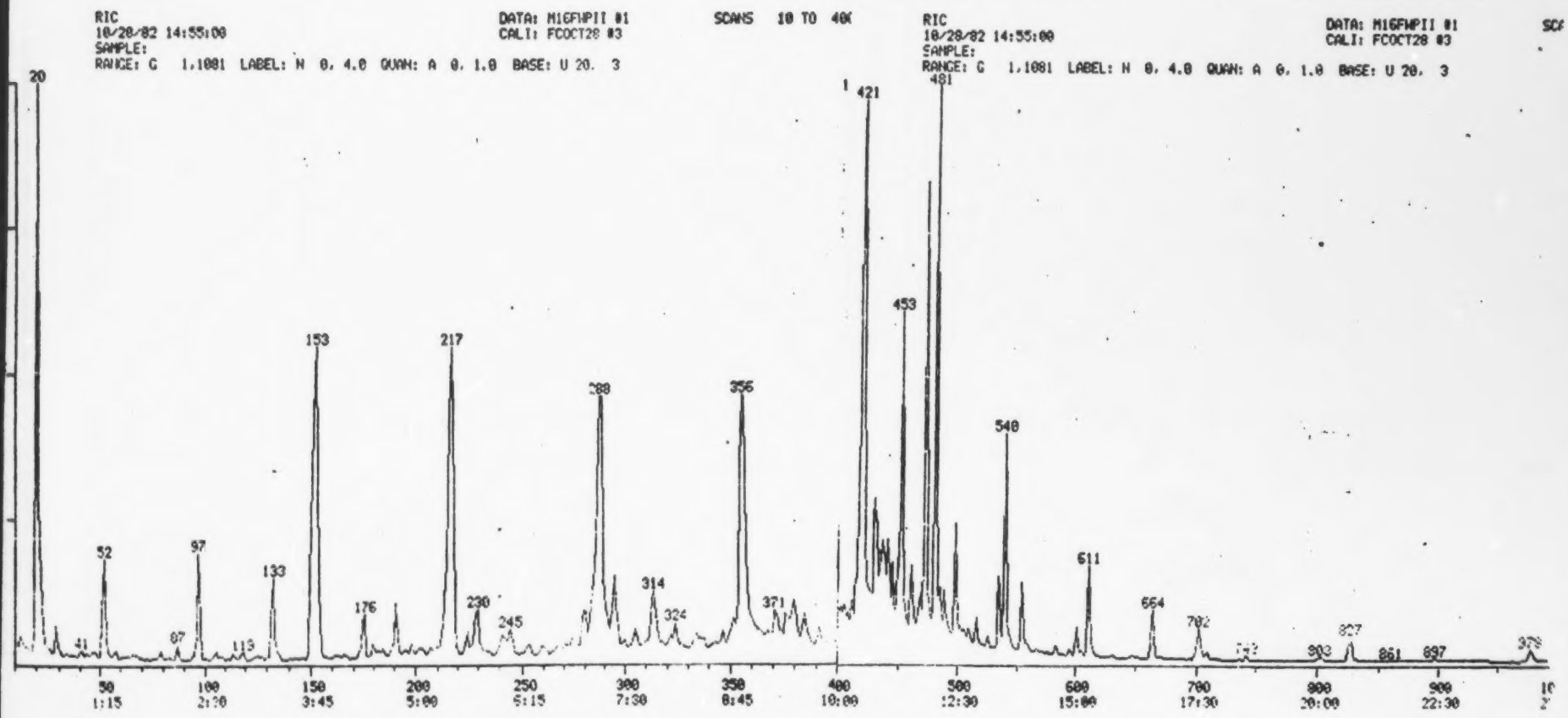

FIGURE 14.

Reconstructed Ion Chromatogram

Sample - M17

Location - Pulp Mill

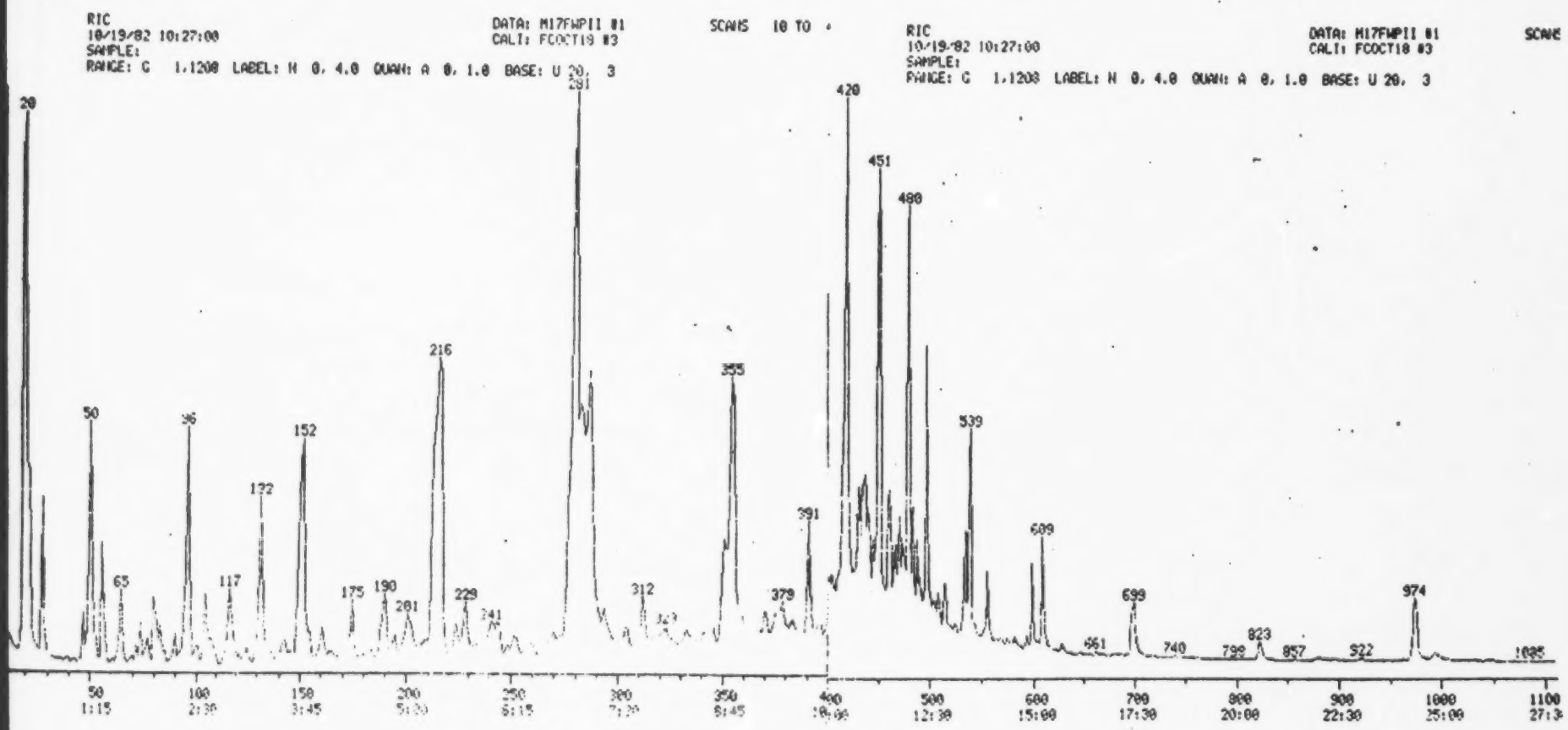

FIGURE 15.

Reconstructed Ion Chromatogram

Sample - M18

Location - Pulp Mill

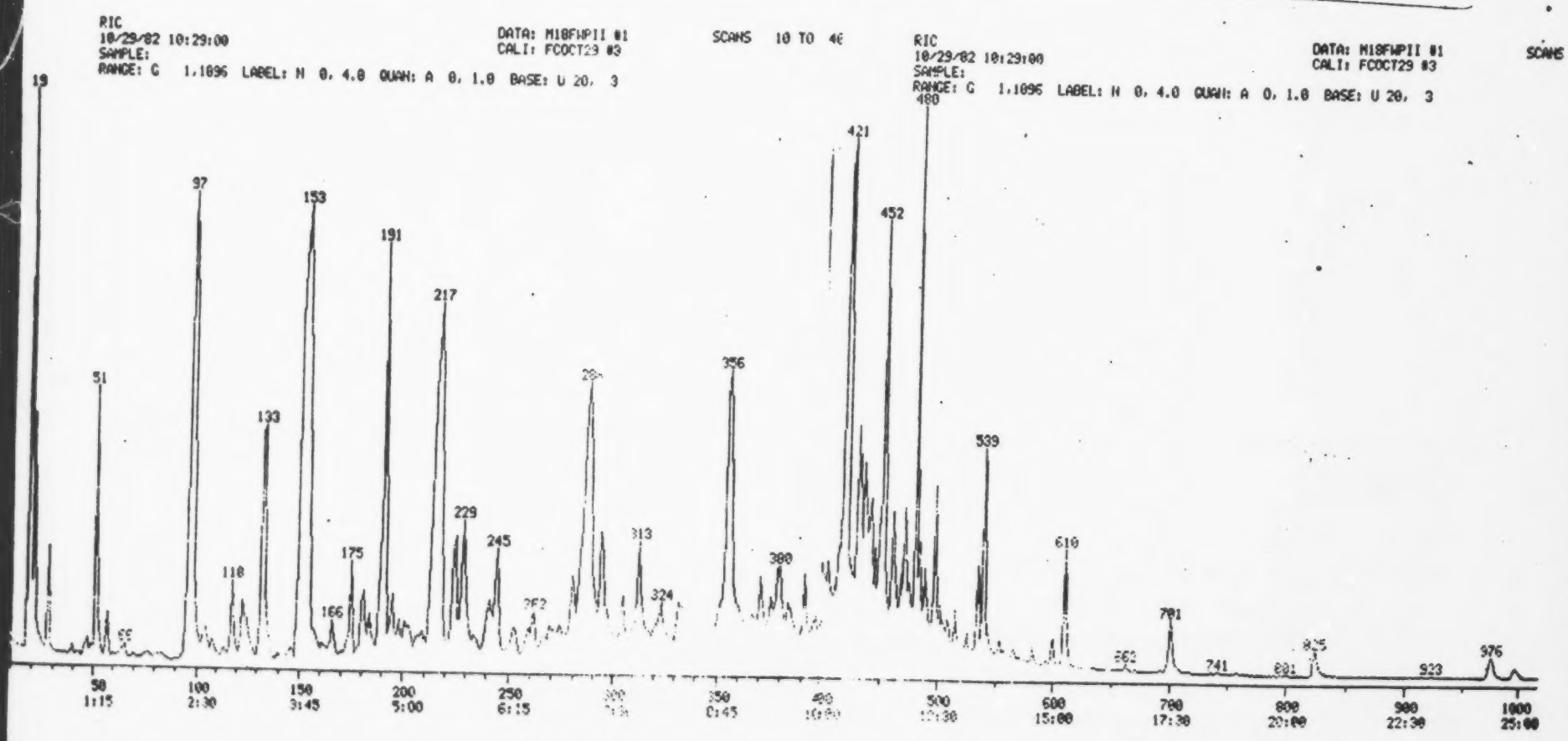

FIGURE 16.

Reconstructed Ion Chromatogram

Sample - M19

Location - Pulp Mill

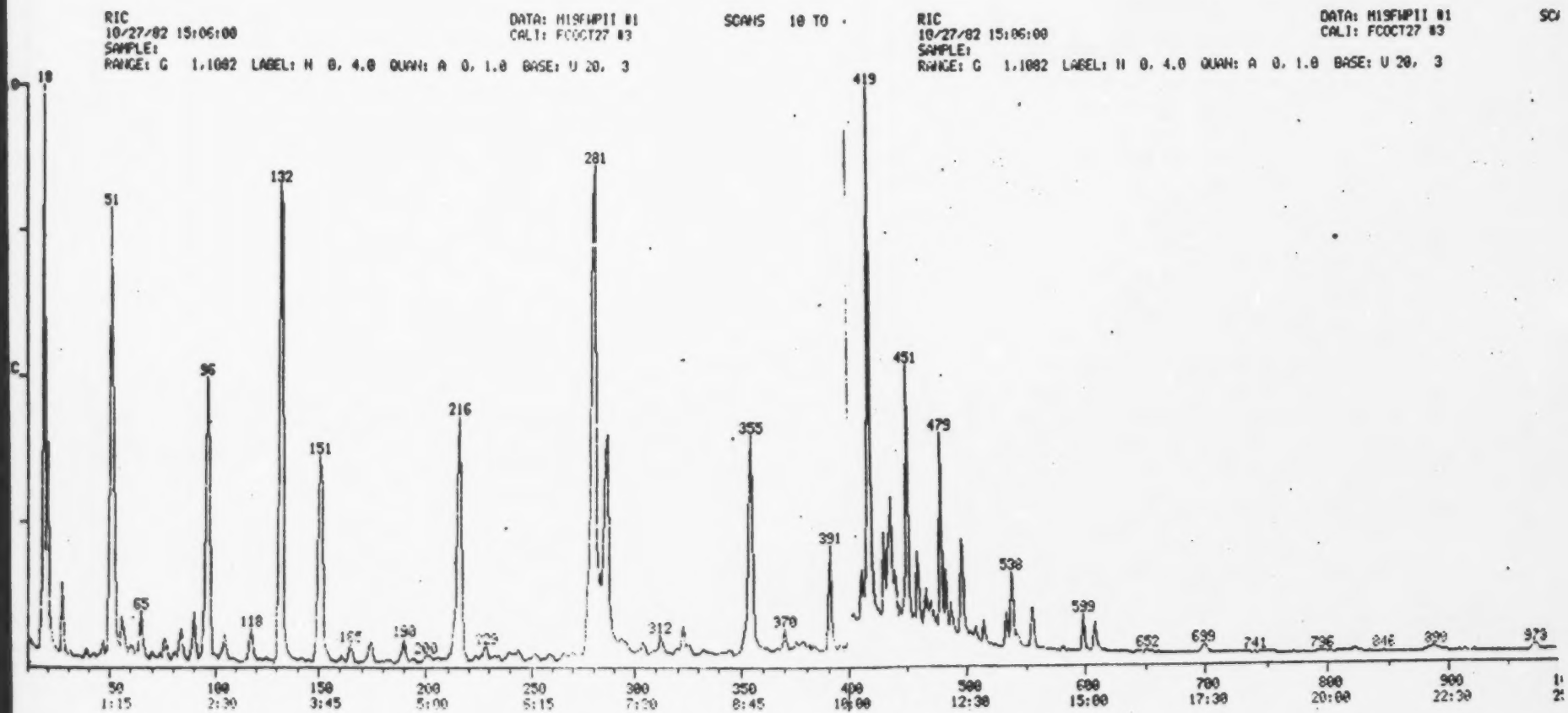

FIGURE 17.

Reconstructed Ion Chromatogram

Sample - 01

Location - Lameque

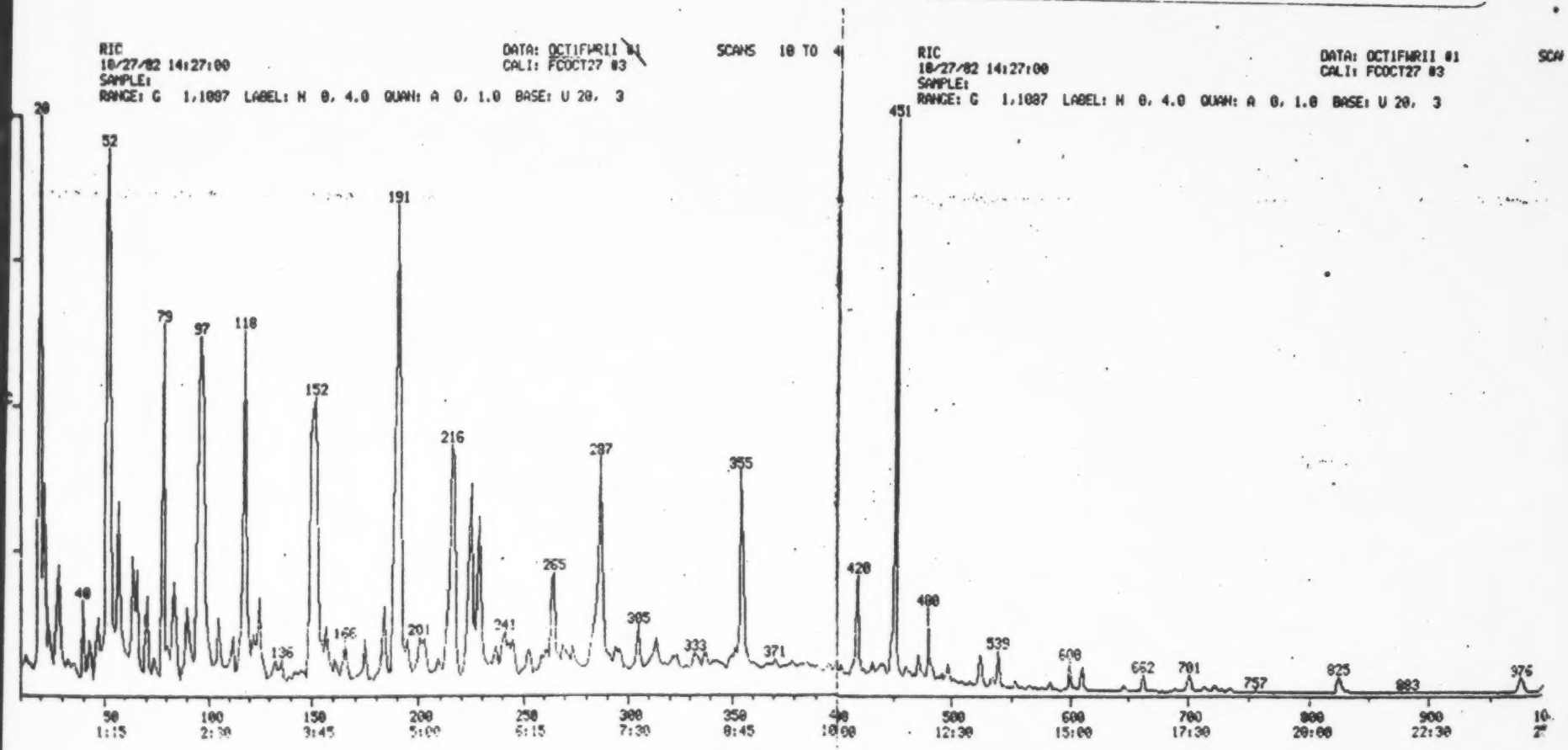

FIGURE 18.

Reconstructed Ion Chromatogram

Sample - 02

Location - Lameque

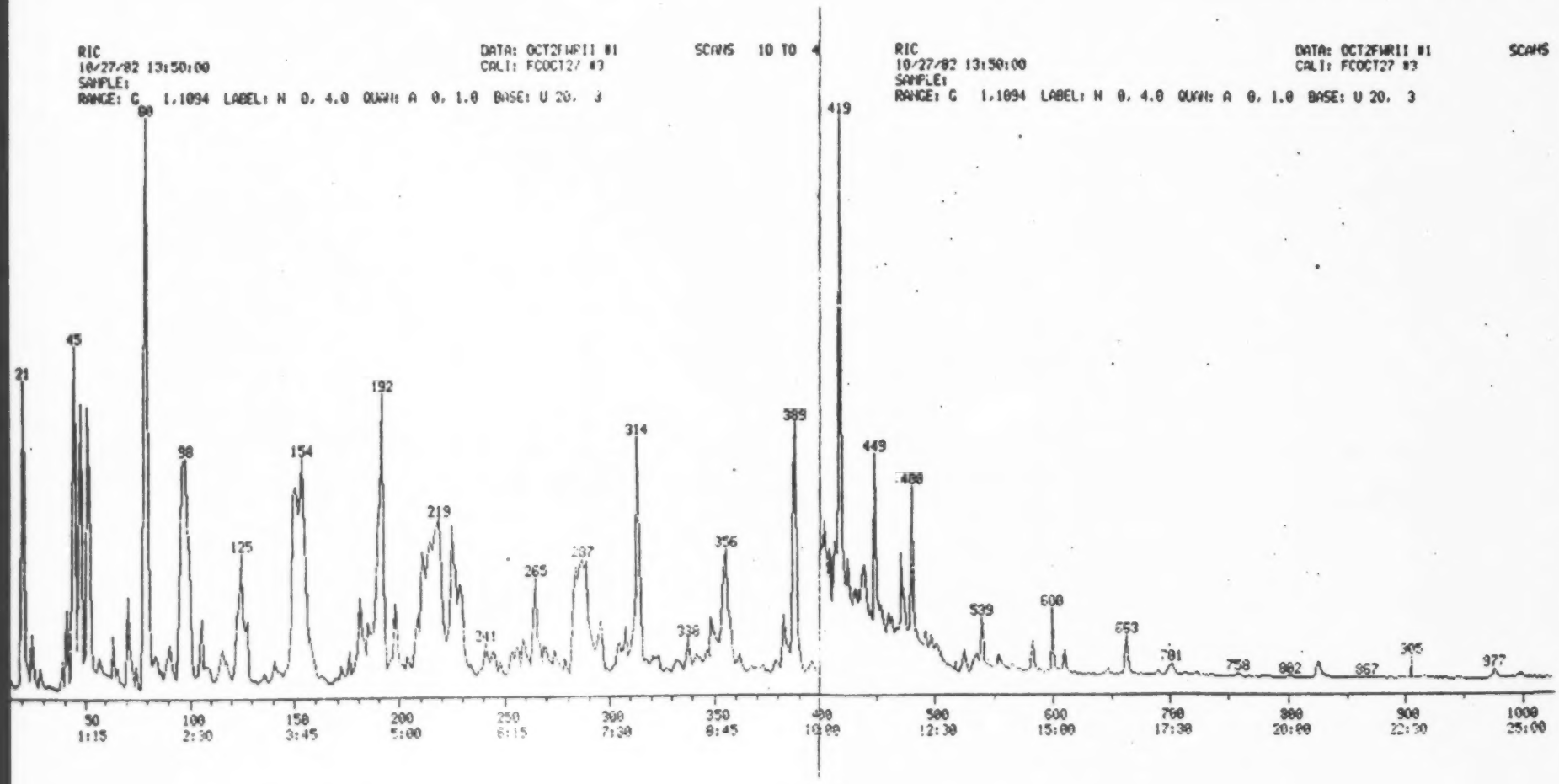

FIGURE 19.

Reconstructed Ion Chromatogram

Sample - 03

Location - Lameque

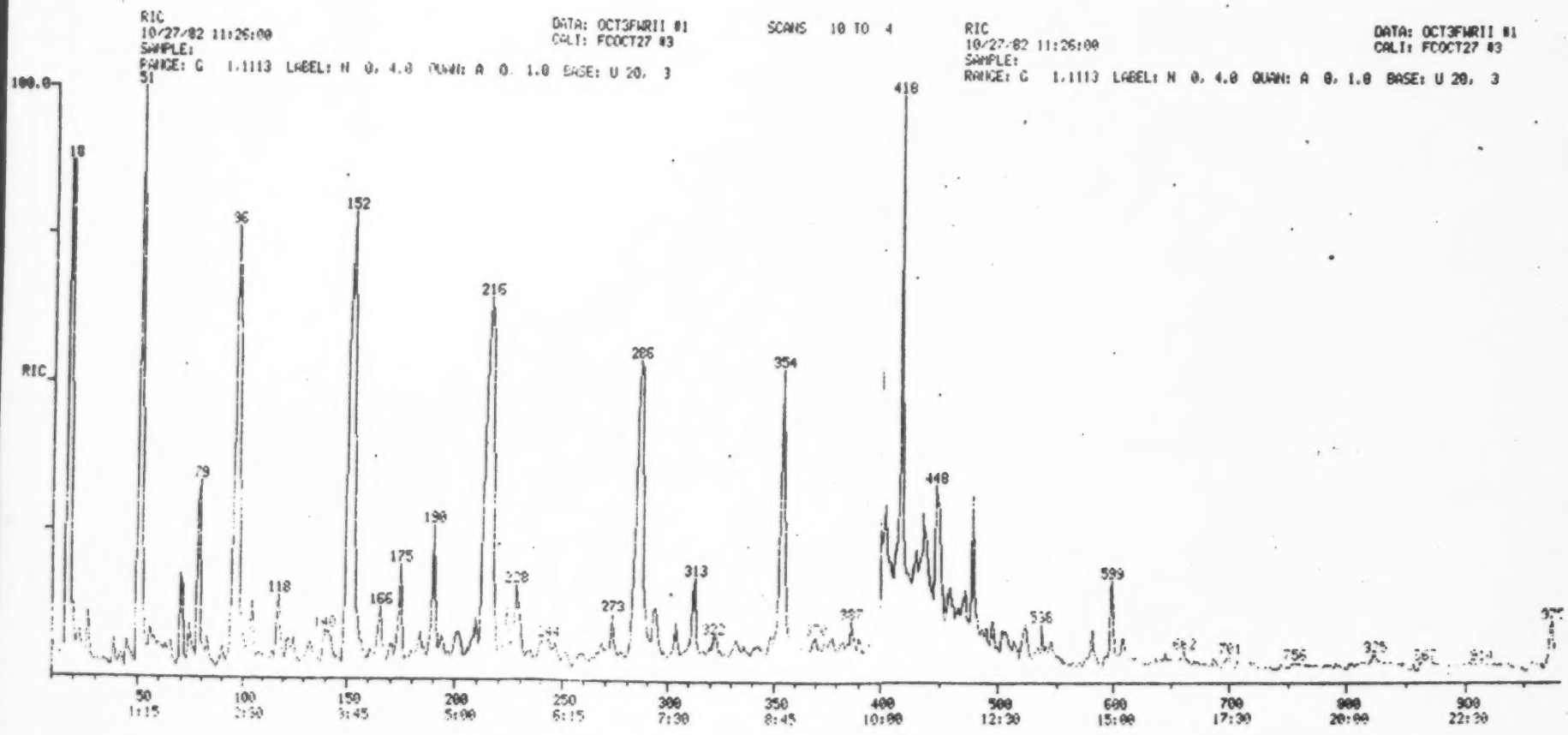

FIGURE 20.

Reconstructed Ion Chromatogram

Sample - 04

Location - Lameque

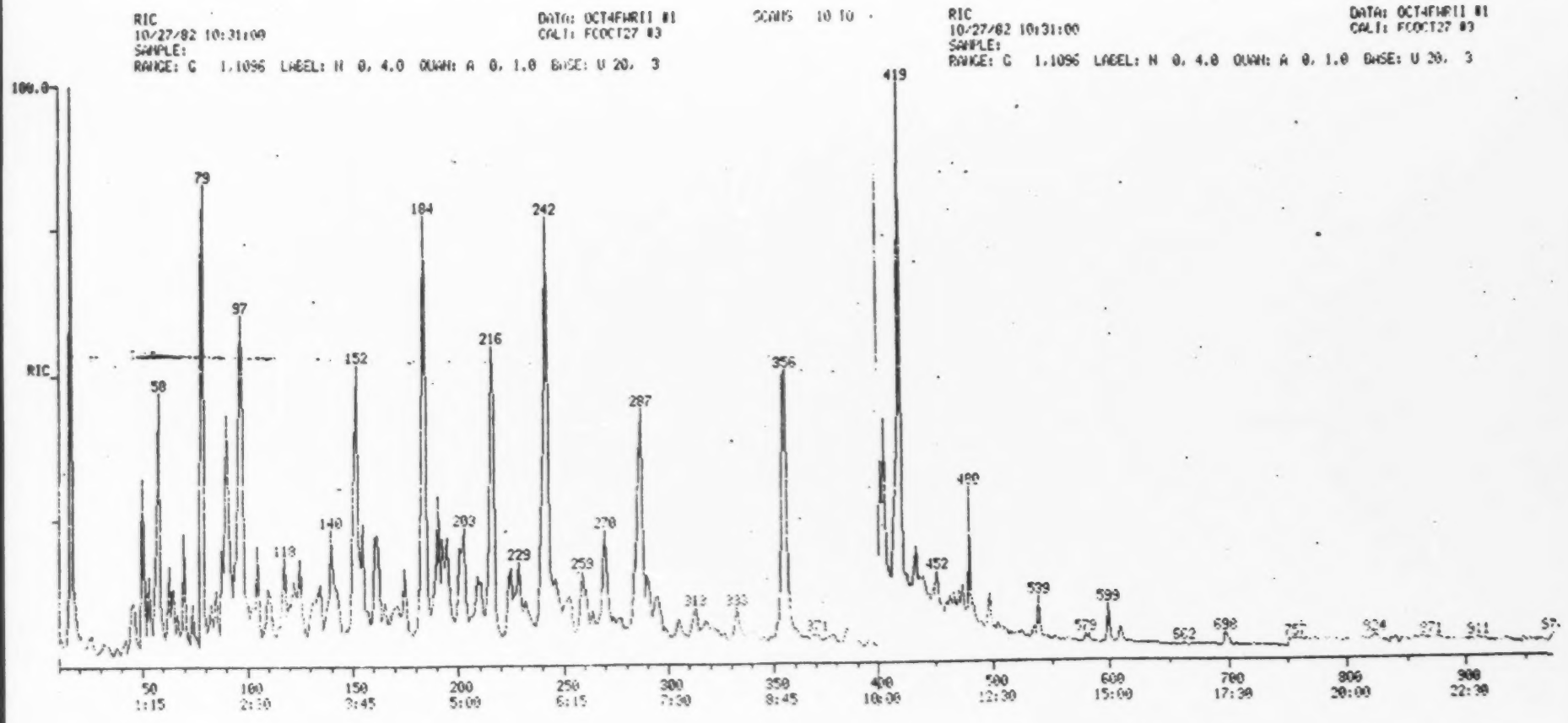

FIGURE 21.

Reconstructed Ion Chromatogram

Sample - 05

Location - Lameque